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NUTRIENT REQUIREMENTS OF DOMESTIC ANIMALS

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Nutrient Requirements of Beef Cattle

Sixth Revised Edition, 1984






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Sixth Revised Edition, 1984

Subcommittee on Beef Cattle Nutrition
Committee on Animal Nutrition
Board on Agriculture
National Research Council



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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

This report is one of a series issued under the direction of the Committee on Animal Nutrition, Board on Agriculture, of the National Research Council. It was prepared by the Subcommittee on Beef Cattle Nutrition and replaces the fifth revised edition of *Nutrient Requirements of Beef Cattle*, issued in 1976.

The report has been completely rewritten and updated. The main points of the revision are as follows:

1. Requirements for growing and finishing cattle are presented on the basis of medium- and large-frame animals.
2. Energy requirements and energy contents of feed-stuffs for beef cattle have been recalculated from a larger data base.
3. Sections have been included on processing of feed-stuffs and environmental influences on nutrient requirements of beef cattle.
4. The section on ration formulation has been deleted and is replaced by a section on prediction equations to permit estimates of feed intake, energy, protein, calcium and phosphorus requirements, and weight gain.
5. A table is presented on estimated water intake of cattle.
6. A separate table for composition of mineral supplements has been added. The text on minerals has been expanded.

To all individuals who contributed to this manuscript, the subcommittee expresses appreciation. In particular, the subcommittee expresses its thanks to Clarence B. Ammerman, Floyd M. Byers, Danny G.

Fox, and Rodney L. Preston, who reviewed the report and provided insightful comments and suggestions for the subcommittee's consideration.

Review of this report was accomplished through the advice and guidance of the members of the Committee on Animal Nutrition. The subcommittee is indebted to Philip Ross, Deputy Executive Director, and Selma P. Baron, Staff Officer, of the Board on Agriculture, for their assistance in the preparation of this report. The subcommittee is especially grateful to Joseph P. Fontenot, who served as coordinator for the Board on Agriculture for the review of this report.

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1 Introduction

With finite land resources and increasing world population, the use of animals is required to maximize food production and maintain the quality of life. Efficient animal production is not possible unless nutrient requirements are met. This edition of *Nutrient Requirements of Beef Cattle* is an extensive revision of the fifth edition, published in 1976.

Types of beef cattle have changed in response to economic pressures and consumer demand for leaner meats. The basic biology of all beef cattle is similar, but differences in mature size and rate of maturing have a marked influence on application of basic nutrition principles to the wide range of environmental and management conditions of practice. For this reason, the frame size of the animal has been considered in calculating nutrient requirements. The medium-frame steer was considered to have 450 to 520 kg live weight at usual market finish and the medium-frame heifer, 400 to 475 kg. The finished weight was considered to be over 520 and 475 kg for large-frame steers and heifers, respectively. Requirements are given for yearling steers and heifers showing compensatory growth (compensating yearling heifers and steers). Nutrient requirements have been determined for growing and finishing bulls, as bull feeding for carcass beef has become an important segment of the cattle feeding industry.

Growing and finishing cattle requirements for energy, protein, calcium, and phosphorus in amounts per day are presented in separate tables. Nutrient requirements expressed as nutrient concentrations in diet dry matter have been calculated from estimated feed intake and are presented in airdupois units. For the breeding herd, daily nutrient requirements and nutrient requirements expressed as nutrient concentrations in diet dry matter are presented in the same table. They are expressed in both metric and airdupois units in separate tables.

Net energy requirements and net energy contents of feeds have been recalculated from a larger data base. Requirements are listed on a live weight (shrunk) basis. Since animal requirements and feed values have been altered, it is inappropriate to use previous requirements or feed values in conjunction with information in this edition. The energy values given for the same International Feed Number (IFN) for a feed in the third revision of *United States-Canadian Tables of Feed Composition* (NRC, 1982) are not appropriate because equations for calculating ME, NE_m, and NE_g are different. The equations used for calculating the energy values given in Table 8 are from equations given in the Energy section in Chapter 2 and on page 38.

An estimate of feed intake is necessary to calculate protein requirements and to list nutrient needs on a concentration basis. Feed intake equations have been developed for this purpose.

Digestible protein is no longer listed in tables, and crude protein requirements have been calculated factorially from equations that are presented in the Protein section. Protein requirements as given in this report do not consider safety margins, and the reader is referred to the discussion in the Protein section. Slight adjustments have been made in phosphorus requirements and major adjustments in calcium requirements, as true digestibility of calcium was considered to be 50 percent.

The feed composition table (Table 8) has been rearranged, and data on plant cell wall constituents have been added where they were available. Common mineral supplements used in cattle feeding appear in a separate table.

A list of formulas for calculating nutrient requirements for various classes of beef cattle has been added to simplify application of these requirements to computer use.

Nutrient Requirements: Excesses and Deficiencies

2

ENERGY

Energy is an abstraction and can be measured only in reference to some defined standard conditions. Nutritionists now standardize their combustion (bomb) calorimeters using specifically purified benzoic acid, the caloric value of which has been determined in electrical units and computed in terms of joules/g mole. The calorie has, therefore, been standardized to equal 4.184 joules (Moore, 1977). This is approximately the amount of heat required to raise the temperature of 1 g of water from 16.5° to 17.5°C. The joule and the calorie are interchangeable, and each is a defined unit; neither is more absolute. The calorie represents a small amount of energy; thus, the kilogram calorie (1 kcal = 1000 calories) and the megacalorie (1 Mcal = 1,000,000 calories = 1000 kilocalories) are more convenient to use in conjunction with animal feeding standards.

Gross energy (E) is the heat released (heat of combustion) when an organic substance is completely oxidized to carbon dioxide and water. Gross energy is related to chemical composition. For example, Nelring and Haenlein (1973) relate gross energy of feedstuffs to their proximate constituents by the relationship:

$$E, \text{ kcal/100 g} = 5.72 (\text{crude protein, percent}) + 9.5 (\text{ether extract, percent}) + 4.79 (\text{crude fiber, percent}) + 4.03 (\text{nitrogen-free extract, percent}).$$

Gross energy contained in a feedstuff is of limited use for assessing the value of a particular ingredient or diet as an energy source for animals. It does not provide information regarding the availability of the energy to the animal.

Expressing Energy Values of Feedstuffs

The gross energy of a food minus the energy lost in the feces is termed digestible energy (DE). An approximately equivalent term, total digestible nutrients (TDN), attempts to measure digestible energy in weight units. TDN has no advantages over DE as the unit to describe feed values or to express animal requirements (Maynard, 1953). TDN can be converted to DE by the relationship 1 kg of TDN = 4.4 Mcal of DE (Schneider and Flatt, 1975). DE has the advantage of ease of measurement but fails to consider all losses of energy associated with the digestion and metabolism of food nutrients. The major weakness of DE as a basis for feeding systems is that it overestimates the available energy of high-fiber feedstuffs (hays, straws) relative to low-fiber, highly digestible products, such as grains.

Metabolizable energy (ME) is a measure of the dietary energy available for metabolism after energy losses that occur in the urine (UE), and the combustible gases (chiefly methane) are subtracted from digestible energy. ME has many of the same deficiencies as a basis for feeding systems as DE, because urinary energy losses and energy lost as methane are relatively predictable from DE; therefore, DE and ME are highly correlated. ME is most valuable as the starting point for nearly all systems of feed evaluation that are based on net energy concepts.

Classically, net energy is the net quantity of energy that is recovered (RE) in an animal product. RE can be a negative quantity for animals fed below their maintenance requirements. The use of net energy as the basis for a system of feed evaluation is complicated by the fact that the ME available from an animal's diet is used at

different levels of efficiency depending on the physiological state of the animal (maintenance, growth, lactation, pregnancy) as well as the makeup of the diet. These complications have been partially accounted for in a net energy system for beef cattle by the convention that assigns two net energy values to each feedstuff. Animal requirements for energy are similarly subdivided. Net energy available or required for maintenance is termed NE_m , and net energy available or required for growth is termed NE_g (Lofgreen and Garrett, 1968; NRC, 1981a). Two major advantages of the net energy system are: (a) animal requirements stated as net energy are independent of the diet, i.e., do not have to be adjusted for different roughage-concentrate ratios, and (b) feed requirements for maintenance are estimated separately from feed needed for the productive functions.

Interconversions between DE, ME, and NE values of feedstuff are possible. The following relationships have been estimated (all units are Mcal/kg DM):

$$ME = 0.82 DE \text{ (NRC, 1976; ARC, 1965).}$$

$$NE_m = 1.37 ME - 0.138 ME^2 + 0.0105 ME^3 - 1.12 \text{ (Garrett, 1980a).}$$

$$NE_g = 1.42 ME - 0.174 ME^2 + 0.0122 ME^3 - 1.65 \text{ (Garrett, 1980a).}$$

Animal Requirements for Energy

The maintenance requirement for energy can be defined as that amount of feed energy that will result in no loss or gain in body energy. For some beef animals near their mature size (adult bulls, for example), maintenance may be the usual physiological state and the practical feeding goal. Maintenance in most other beef animals is more a theoretical condition that differs from the usual physiological or practical state. Nevertheless it is convenient and appropriate to consider maintenance energy requirements separately from any production requirement. Net energy required for maintenance is, by definition, the amount of energy equivalent to the fasting heat production. The NE_m requirements for maintenance of beef cattle have been estimated as 77 kcal/ $W^{0.75}$; W is body weight in kilograms (Lofgreen and Garrett, 1968; Garrett, 1980a). Maintenance requirements estimated by this expression are most applicable for penned animals in nonstressful environments with minimal activity. There are variations in maintenance requirements based on sex and breed (Garrett, 1971; Frisch and Vercoc, 1977; Webster, 1978). Physiological age also has an influence (Geay, 1982). The magnitude of these effects appears to be from 3 to 14 percent. In general, breeds and individuals maturing at heavier weights may require more, and *Bos indicus* breeds and crosses may require less energy for maintenance than would be estimated by the expression $77 W^{0.75}$.

The efficiency of ME utilization must be considered in order to estimate the quantity of ME or DE (TDN) required for maintenance. The efficiency of ME use for maintenance or gain can be calculated for feedstuffs or mixed diets by using the relationship between NE_m and ME or NE_g and ME. Some values are given as examples in the table below. TDN and DE requirements were obtained by the conversion 1 kg TDN = 3.62 Mcal of ME and DE = ME/0.82 (NRC, 1976).

Efficiency of ME Use for Maintenance and Gain

ME Concentration (Mcal/kg)	Approximate Roughage: Concentrate ^a	Efficiency of ME utilization	
		Maintenance	Gain
2.0	100:0	57.6	29.6
2.2	83:17	60.8	34.6
2.4	67:33	63.3	38.5
2.6	50:50	65.1	41.5
2.8	33:67	66.6	43.9
3.0	17:83	67.7	45.8
3.2	0:100	68.6	47.3

^aAssuming average quality roughage contains 2.0 Mcal/kg and that the average concentrate contains 3.2 Mcal/kg.

The NE requirements for growth (NE_g) are estimated as the amount of energy deposited as nonfat organic matter (mostly protein) plus that deposited as fat. The caloric value of fat is 9.4 kcal/g, and for the nonfat organic matter an average value is 5.6 kcal/g. The quantities of protein and fat being deposited are related to two factors: (a) the intake of energy above the maintenance requirement (assuming all other nutrient requirements are also satisfied) and (b) the impetus to grow (i.e., the phase of growth or weight obtained relative to mature weight). For most conditions (continuously grown animals or mature animals without severely depleted energy stores), the energy content of a unit weight gain will be between 1.2 and 8.0 Mcal/kg. These figures are the energy content of the fat-free body (73 percent water, 22 percent protein, 5 percent minerals) (Reid et al., 1955; Garrett and Hinman, 1969) and an average energy content of adipose tissue. The composition of adipose tissue is variable between depots and with the total fatness of the animal, but it is unlikely to contain more than 85 percent fat as an average of all depots (Berg and Butterfield, 1976; Loveday and Dikeman, 1980). All relationships to estimate the caloric value of weight gain have been determined for some particular breeds and sex classes and therefore may have to be adjusted for most precise use for other breed types and conditions (see ARC, 1980, for a review). The relationship between retained energy (RE) and an observed weight gain is also influenced by the contents of the digestive tract, which can vary from less than 5 percent to 21 percent of the

shrunk weight of cattle (Kay et al., 1970; Garrett, 1974a; Jesse et al., 1976; ARC, 1980) depending on the diet and the weighing conditions.

The primary relationships (data from Garrett, 1980a, and Garrett, unpublished) used to estimate the caloric value (RE is equivalent to the NE_g requirement) of the daily empty body weight gain (EBG) of medium-frame British breed steers and heifers receiving hormonal adjuvants are:

$$\text{For steers: RE} = 0.0635 W^{0.75} \text{EBG}^{1.097} \quad (1)$$

$$\text{For heifers: RE} = 0.0783 W^{0.75} \text{EBG}^{1.119} \quad (2)$$

Equivalent relationships in logarithmic form are:

$$\text{For steers: Log (RE/W}^{0.75}) = 1.097 \log \text{EBG} - 1.197$$

$$\text{For heifers: Log (RE/W}^{0.75}) = 1.119 \log \text{EBG} - 1.106$$

In these equations, daily EBG and animal weight (W) are in kilograms on an empty body basis. The unit for RE is Mcal/day. The NE_g is equivalent to the RE.

These basic relationships are easily modified for application to specific practical conditions. For example, information summarized by Garrett (1980a) indicates that cattle that have not received hormonal adjuvants contain about 5 percent more energy per unit gain. The steer equation modified for application to nonimplanted animals would be:

$$\begin{aligned} \text{RE} &= 1.05 (0.0635 W^{0.75} \text{EBG}^{1.097}) \\ &= 0.0667 W^{0.75} \text{EBG}^{1.097} \end{aligned} \quad (3)$$

Other modifications of the primary equations (1 and 2) can be made to estimate RE or NE_g requirements of cattle with other frame sizes or sex classes. An example modification of equation 1 to make it more suitable for use with large-frame steer calves and medium-frame bulls follows.

The assumption is that energy retention of a large-frame calf or medium-frame bull is approximately equivalent to a medium-frame steer of a 15 percent lighter weight. Equation 1 becomes:

$$\begin{aligned} \text{RE} &= 0.0635 (0.85 W)^{0.75} \text{EBG}^{1.097} \\ &= 0.0562 W^{0.75} \text{EBG}^{1.097} \end{aligned} \quad (4)$$

Other modifications of the primary equations (1 and 2) have been made to estimate the energy requirements of large-frame bulls and heifers (see Prediction Equations).

The examples given in the preceding paragraphs are meant to illustrate that general relationships between EBG and energy gain need adjustments for specific conditions in practice. The extent of the modification necessary is related to differences in body composition relative to weight and age and the influence of these

variables on energy utilization (Garrett, 1971; Webster, 1978; Byers and Rompala, 1980; Garrett, 1980b).

The primary equations (1 and 2) and the modified versions discussed are on an empty body weight basis. Under practical conditions, empty body weights and EBGs are not known. The previous edition of this report (NRC, 1976) did not make a distinction between empty body weight and live weight (LW). The present subcommittee has decided to list the requirements in Tables 1 and 2 on an LW basis. LW is defined as weight after an overnight feed and water shrink (generally equivalent to about 96 percent of unshrunk weights taken in the early morning). The decision to list requirements on an LW basis makes it necessary to modify the primary energy requirement equations. Two adjustments are necessary: (1) EBG should be adjusted to a shrunk weight gain (LWG) basis. A multiple regression equation calculated from a data set with observations from 3500 cattle receiving various diets (Garrett, unpublished) is $\text{EBG} = 0.93 \text{LWG} + 0.174 \text{NE}_m - 0.28$; $r = 0.96$; $\text{SE} = 0.014$; (2) The mean live weight (MLW) determined as $[0.5 (\text{initial weight} + \text{final weight})]$ should be adjusted to a mean empty body weight (MEBW) basis. The same data set (Garrett, unpublished) gives the following multiple regression:

$$\begin{aligned} \text{MEBW} &= 0.88 \text{MLW} + 14.6 \text{NE}_m - 22.9; r = 0.98; \\ \text{SE} &= 1.5. \end{aligned}$$

These equations could be substituted directly in the primary energy equations to estimate retained energy (NE_g requirements for LWG). However, the relationships were established under specific experimental conditions, and it is not known how applicable they are to weights and weight gains observed under the widely varying conditions of cattle production. For this reason the subcommittee adopted the simple approach of using average ratios of EBG to LWG (0.956) and MEBW to MLW (0.891) to adjust the primary equations to an LW basis. The ratios are the coefficients calculated using a no-intercept regression of EBG versus LWG and EBG versus LW from the data set mentioned earlier. This simple approach might be expected to underestimate LW gains of cattle fed high-roughage diets and to overestimate the LW gains of those fed very high concentrate diets. For further information and another approach to the solution of the empty body weight to LW conversion problems, the reader is referred to ARC, 1980, p. 38.

The relationship used to estimate maintenance requirements ($77 \text{ Kcal/W}^{0.75}$ as originally determined) also has weight on an empty body basis. The decision not to adjust this estimate is largely arbitrary. An adjustment related to conversion of LW to empty body weight

would decrease the maintenance estimate. A decreased maintenance requirement under practical (as opposed to the experimental) environments does not (intuitively, at least) seem likely. Also, gut contents have to be carried and maintained at near-body temperatures. Therefore, a refinement of the maintenance estimate may not be appropriate at this time, particularly since any change contemplated would be within the error attached to the unadjusted estimate.

Current information is inadequate to modify the present general system describing the energy value of feeds and the energy requirements of cattle for all conditions encountered in production situations. Users are encouraged to adjust the primary equations to fit their specific practical conditions if continued use of the energy requirements given in the tables or by the equations indicates a consistent over- or underestimation of animal performance. Some other procedures for adjusting generally determined energy requirements to specific conditions have been suggested by Garrett (1976), Webster (1978), ARC (1980), and Fox and Black (1984).

The primary equations to predict energy requirements have been rearranged to estimate daily gain when animal weight and feed consumption are known:

$$\begin{aligned}\text{For steers: EBG} &= 12.341 \left(\frac{\text{RE}}{W^{0.75}} \right)^{0.9116} \\ &= 12.341 W^{-0.6837} \text{RE}^{0.9116}\end{aligned}\quad (5)$$

$$\begin{aligned}\text{For heifers: EBG} &= 9.741 \left(\frac{\text{RE}}{W^{0.75}} \right)^{0.8936} \\ &= 9.741 W^{-0.6702} \text{RE}^{0.8936}\end{aligned}\quad (6)$$

Equivalent relationships in logarithmic form are:

$$\text{For steers: Log EBG} = 0.9116 \log (\text{RE}/W^{0.75}) + 1.091.$$

$$\text{For heifers: Log EBG} = 0.8936 \log (\text{RE}/W^{0.75}) + 0.9884.$$

In these equations, RE is the net energy available for gain. Similar equations for bulls, cattle of other frame sizes, and all relationships modified to an LW basis are given in Appendix Table 10.

Energy deposition in the conceptus of beef females has been determined by Ferrell et al. (1976a) and can be calculated from the data of Prior and Laster (1979). Other information related to bovine fetal growth and weight change of the pregnant cow is available (Eley et al., 1978; Silvey and Haydock, 1978). The gross efficiency of ME use for conceptus development has been estimated as 11 to 15 percent for cattle (Ferrell et al., 1976b) and 12 to 13 percent for sheep (Rattray et al., 1974). The average figure of 13 percent was used to esti-

mate the ME requirement for pregnancy and converted to equivalent NE_m units to express requirements in net energy terms. The relationship used to estimate the pregnancy requirement [kcal/day of NE_m equivalent based on expected calf birth weight and day of gestation (t)] assuming a diet of average quality forage (ME of 2.00 Mcal/kg) is:

$$\begin{aligned}\text{NE}_m &= \text{calf birth weight} \\ &\quad (0.0149 - 0.0000407t)e^{0.05883t - 0.0000804t^2}\end{aligned}$$

The energy requirements for milk production have been estimated from the information available for the dairy cow (NRC, 1978). The requirement can be calculated and expressed in NE_m units since ME is utilized for lactation and maintenance at similar levels of efficiency.

$$\text{NE}_m (\text{Mcal/kg of milk}) = 0.1 (\text{percent fat}) + 0.35.$$

The total energy requirement determined by adding the maintenance and lactation requirements should be adequate to prevent weight loss in most lactating cattle not under environmental stress. Under many practical conditions the beef cow may seasonally lose weight (at calving and during early lactation) and gain weight (late lactation and during the nonlactation period). The possibility for increased calving percentages and maintenance of a once-a-year calving interval may be improved if the cow does not lose weight during late gestation and the breeding season.

The weight increase of thin nonlactating adult beef cows (exclusive of products of conception) probably contains between 5 and 12 percent protein and 50 and 75 percent fat. This is equivalent to 5.5 to 7.5 kcal/kg (Garrett, 1974b; Swingle et al., 1979; ARC, 1980). The average value of 6.5 kcal/kg can be used to approximate the empty body weight gain of thin beef cows.

Very little extra energy is required above maintenance for semen production and replenishment in mature bulls (Flipse and Almquist, 1961; Van Demark and Manger, 1964).

Energy requirements listed in all tables in this report assume the animals are not stressed by environmental conditions. Persistent cold or hot weather may result in cattle being outside the thermal neutral zone appropriate for a given feeding level (NRC, 1981b). In cold stress, additional energy will be required to maintain the animal. During heat stress, appetite will decrease, resulting in lower production by animals fed ad libitum. Since many weather factors (air temperature, wind velocity, precipitation, solar exposure) and many animal factors (age, breed, hair coat, fleshing, period of adaptation, and diet) influence an animal's response to the environment, adjustments in generally stated require-

ments must be on an empirical basis. Information regarding the effect of environment on energy requirements is summarized in Chapter 5 of this publication.

PROTEIN

The pruruminant calf has little rumen function, so protein nutrition parallels that for the nonruminant. Amino acid requirements can be met through milk or milk replacers (Roy and Stobo, 1975). Supplementing with certain amino acids may prove beneficial (Foldager et al., 1977), but urea usefulness is limited (Morrill and Dayton, 1978). Milk substitutes should meet protein requirements specified in the tables in this report, while creep supplements should be formulated to complement the protein and energy supplied by milk and grazed forage. After the rumen becomes functional, 6 to 8 weeks of age depending on diet, the crude protein needs for two systems must be met—the need for nitrogen for microbial fermentation in the reticulo-rumen and the need for post-ruminal amino acids for tissues of the host ruminant.

Microbial Requirements

About 75 percent of the carbohydrate digested by ruminants is fermented by microbes in the rumen. During fermentation, volatile fatty acids, ammonia, methane, and CO₂ are released, and energy is liberated for microbial growth and multiplication. A wide variety of microbial types, including many species of anaerobic bacteria, protozoa, and even fungi, thrive in the rumen. Swept out of the rumen to the abomasum and small intestine with fluid and particles, these microbes typically furnish about half of the protein (amino acids) needed by the ruminant animal. Extensive reviews concerning types, metabolism, and importance of the microbial population of the rumen are available (Bryant, 1973; Smith, 1975; Hespell, 1979).

Ruminal bacteria can use various sources of nitrogen (primarily ammonia and some amino acids and peptides), energy (derived from fermentation), and minerals for growth. Any of these factors can limit bacterial growth since requirements are interrelated. The supply of ammonia can be inadequate when either the intake of protein or the ruminal degradation of protein is low. Ammonia deficiency in the rumen reduces the efficiency of bacterial growth and may reduce the rate and extent of digestion of organic matter in the rumen, which may reduce feed intake. The minimum concentration of ammonia-nitrogen in ruminal fluid needed for bacterial growth and digestion has been estimated by various procedures (Satter and Slyter, 1974; Mehrez et al., 1977; Edwards and Bartley, 1979; Hespell, 1979; Slyter et al.,

1979) with little consensus. Concentrations above 5 mg ammonia-nitrogen per 100 ml generally have not increased bacterial protein production, although higher concentrations may increase both ruminal pH and organic matter digestion.

Ammonia is derived from degradation of protein or nonprotein nitrogen (NPN) in the rumen. Although most bacterial species in the rumen can survive using ammonia as their sole source of nitrogen (Bryant and Robinson, 1963), added protein may stimulate bacterial growth by providing amino acids (Maeng and Baldwin, 1976), essential branch-chained fatty acids (Bryant, 1973), or unidentified factors for ruminal bacteria to incorporate or use. Typically the least costly dietary source of ruminal ammonia is some form of NPN.

Nonprotein Nitrogen

The NPN source most commonly fed to ruminant animals is urea. Urea is rapidly hydrolyzed to ammonia in the rumen, and excessive amounts of absorbed ammonia can prove toxic to the ruminant animal. Proper management procedures are necessary when NPN is fed both to prevent ammonia toxicity and to avoid reduction in feed intake. Single doses of urea at 0.3 to 0.8 g of urea per kilogram of body weight have toxic effects. Toxicity can be avoided by thoroughly mixing urea with the diet and setting the maximum concentration at 1 percent of the diet dry matter or one-third of the total protein in the diet. In typical diets for beef cattle, this concentration usually exceeds the amount that is needed. Slowly degraded sources of NPN help avoid ammonia intoxication. Urea is used more completely when high-energy, low-protein diets are fed. High-concentrate diets will provide more energy for synthesis of bacterial protein from ammonia and will increase the amount of ammonia retained in ruminal fluid due to a lower ruminal pH. Ammonia absorption from the rumen and the likelihood of toxicity decrease as ruminal pH declines (Bartley et al., 1976). When NPN is substituted for protein in a diet, special care in mineral supplementation must be exercised, since most sources of protein provide substantial amounts of sulfur, potassium, and phosphorus, which are absent in NPN sources.

NPN addition to a diet is useful only when the ruminal concentration of ammonia is inadequate for optimal bacterial action to (1) digest organic matter or (2) supply ammonia for microbial synthesis of protein. The amount of urea that can be used in the rumen for synthesis of microbial protein with a specific diet theoretically can be calculated based on the amounts of (1) protein degraded to ammonia in the rumen and (2) bacterial protein synthesis. Bacterial protein synthesis usually is proportional to the amount of energy available in the

rumen. Relationships that have been derived are as follows:

$$\text{Urea potential (g/kg dry feed)} = 11.78 \text{ NE}_m + 6.85 - 0.0357 \text{ CP} \times \text{DEG} \quad (\text{Burroughs et al., 1975}), \text{ and}$$

$$\text{Urea potential (g/kg dry feed)} = 31.64 - 3.558 \text{ CP} + [(945 \text{ NE}_m - 887 - 179 \text{ NE}_m^2)]^{0.5} \quad (\text{derived from Satter and Roffler, 1975}),$$

where CP, NE_m , and DEG are dietary protein (percent), net energy for maintenance (Mcal/kg), and ruminal degradation of protein, respectively. These equations provide similar estimates of the amount of urea that can be supplemented to a diet based on its protein and energy content. Unfortunately, ruminal degradation of dietary protein is difficult to predict. Roughage level, feed intake level, and feed processing influence both degradation of protein in the rumen and energy supply for and efficiency of bacterial growth. Consequently, these equations must be modified for specific feeding and management conditions. Additional research is needed to refine the factors that fit into these equations before the equations can be applied successfully. Several systems have evolved in the past decade that can be used to estimate urea usefulness, protein bypass, and postruminal requirements for ruminant animals. The reader is referred to reviews and symposia for information on and comparison of these systems (Owens, 1982; Owens and Bergen, 1983).

Ruminal Protein Degradation and Bypass

Dietary protein is digested in the rumen to a variable degree depending on feed, bacterial, animal, and time conditions. The balance of the dietary protein that escapes destruction in the rumen and passes to the omasum and abomasum is commonly called *bypass* or *escape* protein. (These terms will be used interchangeably here.) In addition, a small portion of the dietary protein passes directly to the omasum without mixing with ruminal contents. Protein escaping or bypassing ruminal destruction is either digested postruminally or is excreted in feces. Since the extent of ruminal degradation of dietary protein depends on bacterial, animal, and time conditions, in addition to chemical and physical properties characteristic of the protein, degradability is a variable not a constant. Hence, rate and extent of degradation rather than degradability will be discussed here.

In the rumen, most protein that is soluble in ruminal

fluid, plus a variable proportion of the insoluble protein, is degraded to ammonia (Henderickx and Martin, 1963; Chalupa, 1975). Solubility alone is a poor index of the extent of degradation of protein in the rumen (Satter et al., 1977), except possibly with high intakes of a high-concentrate diet. Current information (Chalupa, 1975; Satter et al., 1977; ARC, 1980) suggests that protein from various feedstuffs may be classified into three relative ruminal bypass or escape categories as follows: (1) low bypass (under 40 percent)—soybean meal, peanut meal; (2) medium bypass (40 to 60 percent)—cottonseed meal, dehydrated alfalfa meal, corn grain, brewers dried grains; and (3) high bypass (over 60 percent)—meat meal, corn gluten meal, blood meal, feather meal, fish meal. These estimates do not consider feed processing conditions or animal, dietary, and microbial variables, which can markedly alter bypass, especially for the more rapidly degraded protein sources. These factors act through modifying (1) ruminal retention time for digestion and (2) microbial activity within the rumen. Until these factors are more fully quantitated and the postruminal need for protein is more precisely described, the applicability of specific bypass estimates for various feedstuffs is limited. Amino acid composition of bypassed protein from a feedstuff may not parallel that of the total protein in the feedstuff (Macgregor et al., 1978). When high bypass protein is fed, the amount of NPN needed will increase since less dietary protein is degraded to ammonia in the rumen. Increased bypass or escape does not ensure increased animal production, however, since (1) bypassed protein may be poorly digested in the small intestine, (2) the balance of amino acids in postruminal protein may be poor, or (3) energy supply or nutrients other than amino acids may be limiting animal production.

Postruminal Supply and Requirements

The supply of protein to the small intestine is the sum of the fed protein that escapes or bypasses ruminal destruction and the microbial protein synthesized within the rumen. Efficiency of microbial growth varies with specific culture conditions, such as pH, dilution rate, and limiting nutrients. Microbial protein synthesis is usually correlated with the amount of organic matter digested in the reticulo-rumen. Microbial crude protein synthesized in the rumen ranges from 77 to 270 g/kg of organic matter fermented (mean of 151; Thomas, 1973). Higher values are characteristic of roughage diets and faster bacterial growth rates.

Efficiency of converting feed protein or nitrogen to nonammonia nitrogen leaving the rumen is variable. Ruminal output as a percentage of protein intake may exceed 100 percent. Nitrogen recycled to the rumen can

be used for protein synthesis by ruminal microbes, resulting in ruminal output of protein being greater than protein intake, especially when feeding low-protein diets or diets containing large amounts of protein, which is not degraded in the rumen. In contrast, when ruminal degradation of protein is high, or the amount of ammonia available exceeds the bacterial need, ruminal protein output will be less than the amount of protein consumed. In most experiments, protein flow out of the rumen has been between 75 and 120 percent of protein fed and generally is near 100 percent with typical diets containing 11 to 12 percent crude protein. In this publication an efficiency of converting (CE) dietary protein to ruminal protein output of 100 percent was assumed to calculate dietary protein needs from post-ruminal protein requirements. This value should be modified when information on ruminal bypass and microbial protein synthesis permits.

The crude protein (CP) requirement of cattle can be subdivided into specific metabolic costs or factors. These include metabolic fecal loss (F), endogenous urinary loss (U), scurf loss (S), and synthesized products containing protein, including tissue growth (G), fetal growth (C), and milk produced (M). The factorial equation used in this publication is: $CP = (F + U + S + G + C + M)/(D \times BV \times CE)$. This is derived from the classical equation in which biological value (BV) equals retained plus metabolic and endogenous losses divided by true digestibility (D). Components of this equation can be estimated from animal experiments.

Metabolic fecal protein loss (F) in grams of protein per day appears to be a function of dry matter intake or fecal dry matter excretion. This is the major protein cost for mature ruminants. Further information about the influence of fiber intake on F is needed. The current estimates of metabolic fecal protein (6.25N) loss are 30 g of protein per kilogram of dry matter intake or 68 g of protein per kilogram of dry matter output in feces (NRC, 1978). Metabolic fecal protein estimated from feed intake ($30 \times$ dry matter intake) is greater than that estimated from fecal dry matter output ($68 \times$ fecal output) for all diets with digestibilities over 55 percent. Which equation is more appropriate is uncertain.

Classically, F has been considered to represent tissue protein eroded from the intestinal tract as fibrous matter is pushed through. But since much of the fecal nitrogen is microbial debris, F may originate partially from NPN and not be derived completely from tissue amino acids. If a large proportion of the metabolic fecal protein originates from nonspecific sources of nitrogen rather than completely from nitrogen eroded from the intestinal tract, the dietary protein needed to replace F can be reduced, since the inefficiencies of metabolism

need not be deducted. To calculate F for beef cattle, 99 protein level comparisons in 34 publications over the past 15 years in the *Journal of Animal Science*, *Journal of Dairy Science*, and *Canadian Journal of Animal Science* were reviewed. F was estimated using data from deficient cattle only. Two factors, feed intake and the total of other uses of protein (tissue, urinary loss, scurf loss), were regressed against dietary protein intake. The slopes were interpreted to represent $F/(BV \times D)$ and $1/(BV \times D)$. This permitted F to be calculated. F was estimated to be 33.44 g of protein per kilogram of dry matter intake.

To estimate F, knowledge of feed intakes of various types of cattle at various rates of gain is required. Two equations were derived to estimate feed intake. These equations were: for medium-frame steer calves, large-frame heifers, and medium-frame bulls, daily dry matter intake (kg) = $W^{0.75} (0.1493 NE_m - 0.046 NE_m^2 - 0.0196)$; for breeding females, daily dry matter intake (kg) = $W^{0.75} (0.1462 NE_m - 0.0517 NE_m^2 - 0.0074)$ with NE_m being net energy for maintenance in Mcal/kg and W being the shrunk weight in kilograms. For a smaller- or larger-frame size, shrunk weight in the equation was decreased or increased by 10 percent for steers and heifers and by 5 percent for bulls.

To derive the energy density of the diet needed for cattle gaining at different rates, an iterative equation was used to calculate the energy content of the feed consumed to provide enough energy to support a specified rate of gain and to meet the constraints imposed for intake. NE_m values are minimums for the levels of performance listed, except where feasible NE_m solutions fell below 1.07 Mcal/kg. Since few diets containing less than 1.07 Mcal/kg would be fed, this minimum energy density was used in calculations, and feed supply was considered to be limited for cattle in this category. If feed intake is greater than specified for a class of cattle but the rate of gain and the protein deposition remain as specified, then protein requirements expressed on a grams per day basis will be greater than those listed in the tables in this publication. This increase will equal 62 g more protein daily for every kilogram increase in feed intake because of the increase in metabolic fecal loss. But protein requirement, when expressed as a percentage of the diet dry matter, will be lower than listed in the tables here by 2 to 6 percent for each 10 percent increase in feed intake since required diets always contain more than 62 g of protein in a kilogram of dry matter.

Endogenous urinary loss (U), in grams of protein (6.25N) per day, estimated from protein-free diets, can be calculated from body weight in kilograms (W) as: $U = 2.75 W^{0.5}$. This loss includes a portion of the nucleic acids synthesized by ruminal microorganisms. Ad-

ditional nitrogen is lost in urine as a result of improper ratios of absorbed amino acids and the presence of nucleic acids in nonammonia nitrogen reaching the small intestine. This is accounted for by the biological value adjustment. Skin, hair, and scurf loss (S) in grams per day is estimated from surface area as $S = 0.2 W^{0.6}$ (NRC, 1978).

Tissue protein deposition in the empty body (G) in grams of protein per day has been estimated by comparative slaughter techniques and deuterium dilution procedures. Protein deposition is the multiple of the rate of liveweight gain and the chemical composition of the gain. Composition of tissue gained depends on physiological maturity of the animal and the rate of liveweight gain. Protein deposition rates have been estimated using several equations. Byers and Rompala (1979) suggested that: $G = 0.7108 - 0.1038 \log_{10} EBW + 0.03906 \log_{10} (EBG \times (\text{mature } EBW/EBW))$; where EBW is empty body weight (kg), and EBG is empty body weight gain, as discussed in Chapter 2 of this publication. W. N. Garrett (1980, personal communication) suggested that: $G (g) = ADG \times (0.2422 - 0.0236 \times \text{retained energy/kg gain})$, where ADG is the average daily gain in kilograms. Fox et al. (1982), using data from Simpfendorfer, proposed that for cattle over 250 kg, $G (g) = ADG \text{ in kg} \times (0.235 - 0.00026 \times \text{shrunk weight in kilograms})$. R. D. Goodrich (1968, personal communication) proposed that protein content (percent) of gain was $20.25 - 0.0225 \times \text{shrunk weight in kilograms}$. For growing-finishing cattle, the mean protein deposition for the above equations was calculated over the weight range of 250 to 500 kg and rates of live weight gain from 0.5 to 1.5 kg daily, assuming that a mature weight would be 750 kg. For 350- to 400-kg cattle gaining 1 kg daily, values for these equations are similar. The mean values for protein deposition from these equations were regressed against energy content of weight gained calculated from the net energy equations. The generated equation was: protein deposition (g) = daily gain in kg $\times (268 - 29.4 \times \text{energy content of gain in Mcal/kg})$; $r^2 = 0.964$. As in the net energy equations, protein composition of gain of bulls and large-frame steers was assumed to be equal to that of medium-frame steers of 15 percent lower weight. For medium-framed heifers, the composition of gain was considered to be equal to that of medium-frame steers weighing 15 percent more than the shrunk weight of heifers. These factors are based partly on suggestions of Minish and Fox (1982).

Protein deposition in the products of conception (C) accelerates as pregnancy progresses, but over the last third of pregnancy C averages 55 g per day according to the equation of Prior and Laster (1979). Protein output in milk (M) in grams per day is the multiple of milk pro-

duction and milk protein percentage. Milk production varies with breed but generally ranges from 3 to 10 kg daily (Lamond et al., 1969; Williams et al., 1979), and protein content averages 3.35 percent.

True protein digestibility (D), which is protein digestibility corrected for metabolic fecal loss, and biological value (BV) vary among feedstuffs and dietary conditions. Small-intestinal apparent digestibility of amino acid nitrogen from feed plus microbial protein has averaged 66 percent (Armstrong and Hutton, 1975; Zinn and Owens, 1983), but true digestibility in the total tract is near 90 percent. When estimating nitrogen needs to replace factored use of nitrogen, the higher figure must be used. Digestibility of bypassed protein can vary with feedstuffs and processing methods such as heat treatment. Heating of forage can reduce protein digestibility drastically. True digestibility of feed protein can be estimated through pepsin or acid detergent fiber digestion techniques. Because of heat damage, the true digestibility estimate of feeds may need to be reduced from the 90 percent estimate used in the calculations here.

The BV of microbial crude protein, estimated from studies with nonruminants, has ranged from 66 to 81 percent. The high nucleic acid content of microbial cells is partially responsible for this low biological value. Nitrogen recycling by ruminants will increase apparent BV. For calculating requirements, protein intake of deficient cattle was regressed against total protein use (gain, urinary loss, scurf loss, metabolic fecal protein). This regression revealed an efficiency of use of 60 percent. This factor would be the multiple of BV and digestibility. If true digestibility of protein is 90 percent, BV would be 66 percent. Postprandial infusion of certain amino acids (lysine, threonine, and amino acids containing sulfur) can increase the apparent biological value of microbial protein for steers (Chalupa, 1975). However, supplementation of these amino acids beyond the rumen in growing cattle fed high amounts of higher-energy, urea-supplemented diets has not consistently improved apparent biological value.

Protein requirements estimated by this factorial method were compared with results from the 99 comparisons mentioned previously. Unfortunately, frame size, body condition, previous dietary history, stage of growth, and diet composition were not well specified; thus, the usefulness of this data base is limited. If the rate of gain increased when a higher level of protein was fed (52 cases), dietary protein was deficient. When added protein did not increase rate of gain, protein was adequate. When added protein increased gain, feed intake was increased 75 percent of the time and energetic efficiency was increased 95 percent of the time,

indicating that protein status can influence performance indirectly through feed intake. Compared with this data base, protein requirements estimated by the factorial method underestimated the true requirement in 39 percent of the cases where gain responses were seen to added protein, overestimated the true requirement in 21 percent of the cases where no response was observed to added protein, but correctly predicted response to added protein in 68 percent of the cases, including both deficient and adequately supplemented cattle. The listed requirements should be sufficient for a given class of cattle in 50 percent of the cases. The standard deviation in the protein requirement was 14 percent of the estimated requirement. To calculate adequate requirements for cattle in 84 percent of the trials, an additional 14 percent must be added to minimum protein requirements presented in Tables 2 and 10. Additional protein may be economically justified under certain feeding conditions, but adding an additional 28 percent to the listed values to meet estimated needs in 95 percent of the trials reported in the literature may not be economically feasible.

Because of efficiency of protein use, each gram of dietary protein deficiency should decrease protein deposition by 1.7 g and rate of gain by about 10 g per day. A higher protein level, with a safety margin, may prove advantageous when the cost of protein is low relative to energy. Furthermore, providing protein in amounts higher than specified in the tables in this publication may increase animal performance early in a feeding period, although cattle fed a lower-protein diet will make compensatory gains later. Requirements to maximize gain when starting cattle on feed may be higher than the average requirement for cattle during an entire finishing period. With certain diets, supplemental protein may be withdrawn for heavier cattle when other nutrients are provided in adequate amounts. Compared with previously estimated protein requirements, those listed in this publication recommend higher amounts early in the finishing period and lower amounts late in the finishing period.

Protein is often fed at levels in excess of the absolute requirements of growing cattle because of the low marginal cost of protein. In contrast, feeding protein in excess of requirements is infrequent with lactating beef cows that obtain their other nutrients from grazed forage. The economic sacrifices in performance and reproduction and the potential for use and replenishment of protein reserves must be balanced against the cost of feeding protein to cattle to determine the most economical level of supplementation.

Requirements are no longer presented on a digestible protein basis because metabolic fecal protein makes up a large proportion of the apparently indigestible protein.

Previously, most of the digestible protein requirements and feed protein digestibilities were calculated from crude protein figures.

Requirements on the basis of percentage in the diet have been calculated from feed intake. Amounts per day rather than percentage requirements should be used when feed intakes deviate from listed values. Certain additional factors, such as heat, cold or shipment stress, diet processing, feed additives, estrogenic implants, and previous protein and energy intakes, may alter feed intake, rate of weight gain, and composition of tissue gain. Adjustments for the effects of these factors on feed intake and the rate of protein deposition are discussed in another publication (NRC, 1981) and are not well quantitated.

Protein Deficiencies and Toxicities

Ammonia deficiency in the rumen reduces the rate and extent of digestion and may reduce feed intake. Postruminal amino acid deficiencies also may reduce energy intake and efficiency of feed and protein use. Through recycling nitrogen to the rumen, efficiency of protein use is greatest with a marginal protein deficiency. Requirements for protein listed in Tables 2, 6, 10, and 11 may be inadequate for certain diets and feeding conditions. When protein constitutes less than 10 percent of the dietary dry matter, ammonia may be insufficient for ruminal microbes. The amount of ammonia needed for ruminal microbes can be calculated from the urea potential equations given earlier.

Based on results of the literature survey mentioned earlier, a change in feed intake may be useful as an indicator of protein deficiency. If the intake of feed increases when protein is added to the diet, protein was probably deficient, while if intake does not increase, protein probably was not a limiting factor. Protein concentrations above the table values may increase efficiency of feed use slightly, but the economics of feeding excessive amounts of protein must be carefully considered.

Diets containing up to 40 percent protein have been fed to steers. Feed intake was reduced for several days when protein was added, but no signs of ammonia toxicity were evident (Fenderson and Bergen, 1976). Excesses of NPN or soluble protein may precipitate ammonia toxicity, as discussed earlier.

How Protein Requirements Were Calculated

The method used to estimate protein requirements will be illustrated for a 250-kg medium-frame steer calf gaining 1.2 kg daily. All weights are shrunk weights. First, daily energy needs for maintenance (4.84 Meal)

and gain (4.28 Mcal) were calculated from net energy equations. To calculate the protein requirements for pregnant and lactating cattle, the need for added energy for the developing fetus or for milk production would be added. An NE_m for the diet to be used was estimated and feed intake calculated ($kg = [0.1493 NE_m - 0.046 NE_m^2 - 0.0196] W^{0.75}$). Daily NE_m and NE_g supplies were then compared and with the energy needed for maintenance and gain. The level of NE_m in the planned diet was then decreased or increased until the feed intake predicted by the intake equation matched the need for energy calculated from the net energy equation. For this steer a dietary NE_m of 1.81 Mcal/kg should be consumed in adequate quantities (6.28 kg) to produce a 1.2-kg daily gain. The 6.28-kg intake was used to calculate metabolic fecal protein loss (33.44 g protein per kg of dry matter intake = 210 g). Endogenous urinary protein loss (2.75 $W^{0.75}$) and scurf loss (0.2 $W^{0.75}$) equal 43.5 and 5.5 g daily. Based on energy content of gain (4.28 Mcal NE_g deposited per 1.2 kg weight = 3.56 Mcal/kg gain), the protein deposited is calculated (gain in kg $\times [268 - 29.4 \times \text{energy content of gain in Mcal/kg}] = 196$ g. Protein deposition plus fecal, urinary, and scurf loss totals 455 g per day. (Protein deposition in milk or in the developing fetus if appropriate would be added here.) At a true digestibility of 90 percent, a biological value of absorbed amino acids of 66 percent, and an assumed efficiency of 100 percent for converting dietary protein to protein leaving the rumen, the daily dietary protein need is $455 / (0.90 \times 0.66 \times 1.00) = 766$ g. As a proportion of the dry matter in the diet (6.28 kg), the protein requirement equals 12.2 percent.

An alternative approach is to project intake, performance, and protein requirements for cattle fed a diet containing a specified level of energy. For example, with a diet having an NE_m of 1.6 Mcal/kg fed to a 350-kg large-frame bull, dry matter intake ($0.1493 NE_m - 0.046 NE_m^2 - .0196 \times (1.05 \times W)^{.75}$) should be 8.52 kg per day. Fecal protein loss would be 285 g daily (33.44×8.52). This amount of feed provides energy for maintenance (6.23 Mcal/1.6 Mcal per kg = 3.89 kg feed), leaving 4.63 Mcal NE_g ($[8.52 - 3.89 \text{ kg}] \times 1.0 \text{ Mcal } NE_g$), which will support a daily gain of 1.28 kg ($17.35 NE_g^{.9116} W^{-.6837}$) as calculated from the net energy equations. The energy content of gain is 3.62 Mcal/kg (4.63 Mcal NE_g /1.28 kg) for a daily protein gain of 207 g ($1.28 \times [268 - 29.4 \times 3.62]$). Urinary loss and scurf loss would total 51.4 and 6.7 g protein per day for a total daily protein use of 550 g. With a 90 percent digestibility, a biological value of 66 percent, and a ruminal efficiency of protein output at 100 percent of intake, the crude protein requirement is 926 g per day. As a portion of the predicted dry matter intake (8.52 kg), this equals 10.9 percent crude protein.

The amount of the dietary protein that can be provided as NPN can be solved from the urea utilization equations outlined earlier providing the extent of ruminal degradation of dietary protein can be predicted. Proper management must be exercised to avoid NPN toxicity, as discussed earlier. These equations were derived from the relationships mentioned earlier assuming that all nonprotein nitrogen is degraded to ammonia within the rumen and is used with an efficiency equal to ammonia released from dietary protein. The prediction equations are:

$$IP = (7.128 CP - 11.78 NE_m - 6.85) / (7.128 - 0.0357 DEG) \text{ (calculated from Burroughs et al., 1975), and}$$

$$IP = 2CP - 8.89 - (74.62 NE_m - 70.04 - 14.13 NE_g^{.95})^{0.5} \text{ (calculated from Satter and Roffler, 1975),}$$

where IP is the percentage of intact dietary protein out of which the DEG percentage of the protein is degraded in the rumen. CP is the percentage protein required, and NE_m is in Mcal per kilogram of dry diet. These relationships can be used to determine the minimum amount of intact protein that can be fed when supplemented with NPN. The difference between IP and CP is the amount of dietary protein that can be provided as NPN.

The amount of urea that can be included in the diet for the medium-frame beef steers of the example used previously was calculated assuming that 40 percent of the dietary protein was degraded in the rumen. If the requirement is 12.2 percent crude protein, and 40 percent of the intact protein fed is degraded in the rumen, the amount of intact protein needed is 10.3 and 11.8 percent according to the two equations, respectively. NPN could provide the difference (1.9 or 1.0 percentage equivalents of protein), which is 0.68 or 0.37 percent urea in the diet for this example. When a more extensively degraded intact protein is fed, the amount of NPN that can be used is reduced; with a higher bypass protein, more NPN can be used. These calculations have all the limitations of the urea potential estimates as discussed in the Nonprotein Nitrogen section in Chapter 2.

MINERALS

Discussions concerning calcium, cobalt, copper, iodine, iron, magnesium, manganese, molybdenum, phosphorus, potassium, selenium, sodium and chlorine, sulfur, and zinc are included herein. For each of these minerals, information is presented concerning justification for inclusion as a required nutrient, absorption and excretion, requirements, factors affecting require-

ments, interrelationships with other minerals and vitamins, deficiency signs, toxicity signs, and common sources. For many of the minerals, information on requirements and quantitation of factors that affect requirements is lacking. Users of the information presented here on mineral requirements must recognize that these are influenced by many factors and that single value requirements may be misleading. Though requirements herein are expressed as a percentage of the diet, animal needs are for specific quantities per day. If feed intake differs markedly from that listed in the tables, percentages in the diet may need to be adjusted to maintain adequate intakes of specific minerals. Calcium and phosphorus requirements are presented in detail in Table 3. Requirements and maximum tolerable levels for other minerals are presented in Table 4.

Other elements (aluminum, arsenic, barium, bromine, chromium, fluorine, nickel, rubidium, silicon, strontium, vanadium) have been suggested to be required by a variety of animals. However, little information is available for cattle concerning requirements or deficiency signs for these elements.

Minerals that are lacking in the diet may be force fed in complete nitrogen-vitamin-mineral supplements or by self-feeding common salt-mineral mixtures formulated to provide needed minerals when the mixture is consumed in amounts to satisfy the animals' appetite for common salt. Other than for common salt, animals apparently do not have the ability to select needed minerals.

Presented in Table 5 are maximum tolerable levels (NRC, 1980) of several elements that are known to be toxic to cattle. Maximum tolerable levels of these elements are influenced by a variety of dietary and animal factors. However, amounts of these elements in excess of the levels given are likely to result in adverse effects in cattle.

Calcium

Calcium (Ca) is the most abundant mineral in the body. It is needed for bone formation, development of teeth, production of milk, transmission of nerve impulses, maintenance of normal muscle excitability (along with sodium and potassium), regulation of heartbeat, movement of muscles, blood clotting (conversion of prothrombin to thrombin), and activation and stabilization of enzymes (i.e., pancreatic amylase). Most of the calcium in the body is found in the skeleton and teeth, and these pools constitute approximately 2 percent of body weight. In blood, calcium is found mostly in plasma, with a homeostatically controlled concentration of about 10 mg/100 ml.

Calcium is absorbed actively from the duodenum and

jejunum. The solubility of calcium compounds, and hence the absorption of calcium, is favored by acid conditions and hindered by alkaline conditions in the small intestine. Thus, most calcium is absorbed in the proximal portion of the duodenum. Calcium absorption is depressed by fluorine (Ramberg and Olson, 1970), is greater in young than old animals (Hansard et al., 1954), is greater during periods of low calcium intake than when calcium intake is high, and is depressed during a lack of vitamin D (DeLuca, 1974). Strontium absorption and metabolism parallel those of calcium (Comar et al., 1961).

Several changes occur in response to a lowering of plasma calcium. First, parathyroid hormone is released. It stimulates the production of 1,25-dihydroxy cholecalciferol, a metabolically active form of vitamin D. The 1,25-dihydroxy cholecalciferol increases production of calcium-binding protein in the intestines, and in conjunction with the parathyroid hormone it increases calcium resorption from bone and increases phosphorus loss in urine.

If plasma calcium levels become elevated, calcitonin is produced and parathyroid hormone production is inhibited. Thus, calcium absorption and bone resorption are slowed. The interplay of parathyroid hormone, thyrocalcitonin, and 1,25-dihydroxy cholecalciferol maintains plasma calcium within narrow limits. Therefore, plasma calcium is usually inadequate as a measure of calcium status.

At parturition, dairy cows exhibit a drop of 1 to 2 mg calcium/100 ml plasma calcium. Milk fever may develop if plasma calcium drops below 5 mg/100 ml (Jacobson et al., 1975).

Calcium is excreted mainly in feces with only small quantities appearing in urine. The low urinary loss is due to an effective reabsorption of calcium by the kidney.

Calcium and phosphorus requirements for growing and finishing cattle (Table 3) were calculated on the basis of needs for maintenance plus those for production. Maintenance requirements were calculated as 1.54 g of retained calcium (Hansard et al., 1954, 1957) and 2.80 g of retained phosphorus (Kleiber et al., 1951; Lofgreen and Kleiber, 1953, 1954; Tillman and Brethour, 1958; Lofgreen et al., 1952) for each 100 kg of body weight. Retained calcium and phosphorus needs above maintenance were calculated as 7.1 and 3.9 g, respectively, per 100 g of protein gain. The calcium and phosphorus contents of gains were calculated from data presented by Ellenberger et al. (1950). Calcium and phosphorus needs, above maintenance, during the first 3 to 4 months of lactation were calculated as 1.23 g of calcium and 0.95 g of phosphorus per kilogram of milk produced (NRC, 1978). Milk productions were assumed to be 5 or

10 kg per cow daily. Fetal calcium and phosphorus contents were assumed to be 13.7 and 7.6 g/kg fetal weight. This requirement was distributed over the last 3 months of pregnancy. Average birth weight was assumed to be 30 kg. Total amounts of available calcium and phosphorus for the various classes of cattle were calculated by adding maintenance and production requirements.

These values were converted to dietary calcium and phosphorus requirements assuming a true digestibility for dietary calcium of 50 percent (Hansard et al., 1954, 1957) and a true digestibility for dietary phosphorus of 85 percent (Kleiber et al., 1951; Lofgreen and Kleiber, 1953, 1954). The calcium and phosphorus requirements determined in this manner are in general agreement with those reported by Beeson et al. (1941), Mitchell (1947), Wise et al. (1958), Wentworth and Smith (1961), Baker (1964), Varner and Woods (1968, 1972), and Ricketts et al. (1970). Reports by Call et al. (1978) and Butcher et al. (1979) showed that diets that contained 0.14 percent phosphorus on an as-fed basis met requirements of beef cows. A diet that contained 0.09 percent phosphorus resulted in reduced appetites after 8 to 14 months. The 0.14 percent phosphorus diet would provide only slightly less phosphorus than determined herein, since cattle in the report by Call et al. (1978) weighed only 163 to 377 kg.

Since true digestibilities of calcium and phosphorus in feedstuffs vary, dietary calcium and phosphorus requirements shown in Tables 3 and 7 may in some instances need to be adjusted. Calcium requirements are influenced by such animal factors as age, weight, and type and level of production. Young animals absorb calcium more efficiently than older animals (Hansard et al., 1957), but they have higher requirements because of a higher rate of bone growth. Also, high rates of gain or milk production, high-fat diets, and pregnancy increase calcium requirements. The effect of calcium-phosphorus ratio on the performance of ruminants appears to have been overemphasized in the past. Several studies have shown that dietary calcium-phosphorus ratios between 1:1 and 7:1 result in near normal performance (Dowe et al., 1957; Wise et al., 1963; Smith et al., 1966; Ricketts et al., 1970), providing that phosphorus consumption meets requirements.

A deficiency of calcium results in rickets in young animals and osteomalacia in older animals. Rickets may be caused by a deficiency of calcium, phosphorus, or vitamin D. It is characterized by improper calcification of the organic matrix of bones of young, growing animals. Thus, the bones are weak, soft, and lack density. Signs include swollen, tender joints; enlargement of the ends of bones; an arched back; stiffness of the legs; and development of beads on the ribs. If the condition causing rickets is not corrected, calves will develop bowed and

deformed legs, because of the effects of muscle tension and weight on the weak, soft leg bones. Also, rachitic bones are highly susceptible to fracture.

Osteomalacia is the result of demineralization of the bones of adult animals. Since calcium and phosphorus in bone are in a dynamic state, high metabolic demands on calcium and phosphorus stores, such as occur during pregnancy and lactation, may result in osteomalacia. This condition is characterized by weak, brittle bones that may break when stressed. Dairy cows that have lactated heavily and that have been fed insufficient calcium are prone to develop osteomalacia.

Ruminants tolerate high levels of dietary calcium. Colovos et al. (1957) noted reduced protein and energy digestibilities in dairy heifers fed high levels of ground limestone. Calcium reduces the absorption of tetracyclines, manganese, and zinc (Suttle and Field, 1970). Reduced feed consumption and daily gains may occur when high-calcium diets are fed. A hypercalcemia as the result of excess calcium absorption stimulates the production of calcitonin by the thyroid. Calcitonin inhibits bone resorption. If high dietary levels of calcium are maintained and the body remains under the influence of calcitonin, the cortex of bones may thicken (osteopetrosis) because of continued deposition but limited resorption.

The calcium content of feedstuffs varies greatly. Sources of variation in calcium content include types of plant, portion of plant fed, and stage of maturity. Calcium concentrations in forages generally decline with maturity. Legumes are high in calcium, and the cereal grains are low in calcium. Several of the oilseed meals are good sources of calcium. Sources of supplemental calcium include calcium carbonate, ground limestone, bone meal, dicalcium phosphate, defluorinated phosphate, monocalcium phosphate, and calcium sulfate.

Cobalt

The cobalt (Co) requirement of cattle is actually a cobalt requirement of rumen microorganisms. The microbes incorporate cobalt into vitamin B₁₂, which is utilized by both microorganisms and animal tissues. Vitamin B₁₂ (cobalamin) is of key importance in the utilization of propionic acid. The main physiological manifestation of cobalt or B₁₂ deficiency is impaired propionate metabolism, since it is needed for activity of methylmalonyl-CoA isomerase, an enzyme that catalyzes the conversion of methylmalonyl-CoA to succinyl-CoA (Marston et al., 1961). Vitamin B₁₂ is also a part of the enzyme 5-methyltetrahydrofolate:homocysteine methyltransferase (Gawthorne and Smith, 1974). This enzyme catalyzes the recycling of methionine from homocysteine after the loss of its labile methyl group.

Vitamin B₁₂ is also needed for normal liver folate metabolism.

About 43 percent of the body cobalt is stored in muscles and approximately 14 percent is in bone (Underwood, 1977). However, cobalt stored in tissues does not readily pass to the rumen for synthesis of B₁₂. The remainder of the body cobalt is distributed among other tissues, with the kidney and liver containing the most cobalt. Cobalt levels (dry basis) in kidney, liver, pancreas, spleen, and heart average 0.25, 0.15, 0.11, 0.09, and 0.06 ppm, respectively. Whole blood contains about 0.9 ng of vitamin B₁₂/ml in calves and 0.5 ng/ml in mature cows (Smith and Loosli, 1957).

About 3 percent of ingested cobalt is converted to vitamin B₁₂ in the rumen (Smith and Marston, 1970). Of the total vitamin B₁₂ produced, only 1 to 3 percent is absorbed. The absorptive site is the lower portion of the small intestine. Substantial amounts of B₁₂ are secreted into the duodenum and then resorbed in the ileum. Cobalt and vitamin B₁₂ are mainly excreted in the feces, although variable amounts are excreted in urine (Smith, 1965; Smith and Marston, 1970).

A cobalt concentration of 0.10 ppm in diet dry matter is considered adequate for all cattle (Smith and Loosli, 1957). Other estimates range from 0.07 to 0.11 ppm in the dry matter (Underwood, 1977). Calves may be slightly more sensitive to cobalt deficiency than mature cattle. Cobalt-deficient soils occur in many parts of the world with large deficient areas in Australia, New Zealand, and along the southeast Atlantic coast of the United States (Ammerman, 1970). Cattle grazing in these areas develop deficiency signs ranging from subclinical to acute. If cattle are confined to cobalt-deficient pastures or diets, they appear normal for several weeks or months, depending on age and degree of deficiency (Underwood, 1966). As body stores of vitamin B₁₂ are depleted, a gradual loss of appetite and body weight occurs, followed by extreme anorexia, muscular wasting, and severe anemia, culminating in death. In severe deficiency the mucous membranes become blanched, the skin turns pale, a fatty liver develops, and the body becomes almost totally devoid of fat. Anemia develops after anorexia occurs, which may be a result of propionate accumulation. In extreme cobalt deficiency, plasma glucose levels fall as a result of impaired propionate metabolism. Elevated plasma glutamic-oxaloacetic transaminase and low ascorbic acid levels reflect the severe liver damage. Plasma pyruvate levels are high because of an induced thiamine deficiency. A vitamin B₁₂ level of less than 0.1 µg/g of fresh liver is indicative of a moderate cobalt deficiency, with levels below 0.07 µg/g indicative of severe deficiency (Andrews et al., 1959). Plasma levels of about 0.2 ng/ml are indicative of a cobalt deficiency, although there is

considerable individual variability. The best indicators of a cobalt deficiency are low plasma B₁₂ levels, loss of appetite, and elevated blood pyruvate.

Cobalt toxicity in ruminants is rare because toxic levels are about 300 times requirement levels. Keener et al. (1949) fed up to 110 mg/kg of body weight of cobalt daily to young dairy calves without harmful effects. When calves were fed greater amounts, a mild polycythemia occurred. Other signs of excessive cobalt intake are excessive urination, defecation, and salivation; shortness of breath; and increased hemoglobin, red cell count, and packed cell volume. Cobalt fed as sulfate, chloride, or carbonate was shown to be equally toxic when fed in excess (Keener et al., 1949). Methionine may aid in protecting against cobalt toxicity (Dunn et al., 1952).

Legumes are generally higher in cobalt than grasses, although availability of cobalt in soil causes much variability. Alfalfa may vary from 0.09 to 0.56 ppm cobalt in dry matter (NRC, 1978). Oilseed meals are generally good sources. Cereal grains, particularly corn, are poor, with concentrations of 0.01 to 0.06 ppm. Cobalt can be added to diets or mineral mixes as cobalt oxide or salts such as cobalt sulfate and cobalt chloride. Cobalt sulfate and cobalt oxide administered by drenching were equally effective for lambs grazing cobalt-deficient pastures (Underwood, 1977). A cobalt pellet (composed of cobalt oxide and finely divided iron) that lodges in the reticulum has been successful in preventing deficiency for extended periods in cattle grazing deficient pastures.

Copper

Copper (Cu) is necessary for hemoglobin formation, iron absorption from the small intestine, and iron mobilization from tissue stores. Ceruloplasmin, which is synthesized in the liver and contains copper, is necessary for the oxidation of iron, permitting it to bind with the iron transport protein, transferrin. Copper is also essential in connective tissue metabolism. Lysyl oxidase, a copper-containing amine oxidase, is involved in the crosslinking of polypeptide chains in elastin and collagen (Kim and Hill, 1966; Carnes, 1971). Other enzymes that contain or require copper for biological activity include cytochrome oxidase, uricase, tyrosinase, glutathione oxidase, butyryl coenzyme A dehydrogenase, catalase, aminolevulinic acid hydrazase, ascorbic acid oxidase, laccase, β-mercaptopyruvate transsulfurase, lecithinase, and oxaloacetate decarboxylase.

Normal blood copper levels range from 70 to 170 µg/100 ml in most ruminants (Beck, 1956). Cunningham (1931) reported copper levels in liver, heart, lung, spleen, and kidney from newborn calves of 470.0, 14.8, 4.9, 4.8, and 15.7 ppm in the dry matter of respective

tissues. Normal tissue copper levels vary with dietary intake, species, age, and nutritional status. Hepatic copper concentrations in hypercupremic sheep and cattle may increase 10-fold over normal animals. These high levels of hepatic copper may cause the hemolytic crises that result in death of animals fed high levels of copper (NRC, 1980).

Copper is absorbed from the upper portion of the duodenum. In sheep, considerable absorption takes place from the large intestine (Underwood, 1977). The extent of absorption may be influenced by age, some hormones, pregnancy, and some diseases (Goodrich et al., 1972). Mills (1956, 1958) reported that the chemical form of copper may influence its availability to animals and that neutral or anionic organic copper complexes appear to be more readily absorbed than copper sulfate. Also, several nutrient interrelationships have a profound effect on the absorption of this element.

Hill and Matrone (1970) noted that zinc and silver are antagonistic to copper absorption. Histidine and other amino acids favor the absorption of several metals (copper, iron, zinc) because they prevent the formation of metal hydroxides and metal-phosphates that are poorly absorbed (Forth et al., 1973).

Copper excretion is an active process in which copper is released into bile and ultimately into feces (Underwood, 1977). Trace amounts of copper are excreted in urine, perspiration, and milk. In cases of bile duct obstruction or Wilson's disease (NRC, 1980), copper may be excreted in urine.

Diet concentrations of 4 to 10 ppm copper have generally been considered to meet requirements of beef cattle (Goodrich et al., 1972). Diets with less than 3 to 5 ppm copper may result in subnormal plasma and liver copper levels in cattle. However, dietary levels of molybdenum and inorganic sulfur may influence the amounts of copper required by ruminants. Goodrich and Tillman (1966) determined that supplemental molybdenum or sulfur as sulfate decreased copper retention and storage in livers of sheep. Calves fed milk diets for long periods, older cattle fed forages grown on copper-deficient soils, and animals fed diets high in molybdenum and sulfate may develop copper deficiency signs (NRC, 1980).

Generally, plasma copper levels below 60 $\mu\text{g}/100\text{ ml}$ are indicative of copper deficiency in cattle. However, the first clinical sign of a hypocupremic condition is usually achromatrichia (lack of pigmentation). Low copper intakes reduce the synthesis and activity of the copper-containing enzyme, tyrosinase, which is required for the conversion of tyrosine to melanin. Tyrosinase is required for pigmentation of hair, wool, and feathers (Underwood, 1977).

Amine oxidase is responsible for the oxidation of the epsilon-amino group of lysine, which is necessary for the

crosslinking of polypeptide chains of elastin and collagen. Underwood (1977) noted that hypocupremic animals have decreased levels of amine oxidase and that this factor may predispose fibrosis of the myocardium, thin bones with broadened epiphyseal cartilage, and low osteoblastic activity in bones. Hypocupremic cattle and sheep may develop spontaneous fractures or osteoporosis due to decreased crosslinking in collagen. Starcher et al. (1964) reported that hypocupremic chicks had decreased aortic elastin contents. Sheep that graze on copper-deficient soils may give birth to lambs having "swayback," which appears to be caused by cerebral demyelination (Marston et al., 1948).

Soil concentrations of copper may vary considerably by geographical location. In the United States, some soils have been found to contain more than 37 ppm of copper (Shacklette, 1970). Thus, plants grown in these regions may have high copper contents (NRC, 1980). Also, curing or drying of forages may alter the chemical form of copper, making it more available than copper in fresh green plants (Underwood, 1977) and predisposing animals to copper poisoning.

Copper toxicity is initially characterized by increased serum transaminase and lactic dehydrogenase activities. During the hemolytic crises, blood copper, methemoglobin, and creatine phosphokinase increase, while levels of hemoglobin and glutathione are depressed (NRC, 1980). Hypercupremia in sheep promotes renal tubular necrosis; spongy lesions in the white matter of the brain; dark, stained kidneys; and swollen livers (NRC, 1980). In acute oral toxicity, animals may experience nausea, vomiting, salivation, abdominal pain, convulsions, paralysis, collapse, and death. Hypercupremic conditions may also predispose the animal to anemia, muscular dystrophy, decreased growth, and impaired reproduction (NRC, 1980).

Maximum tolerable dietary levels of copper during growth, as recommended by the National Research Council (1980), are 115 ppm for cattle. Maximum tolerable levels are greater for adults than for young, growing animals.

Grains are generally lower in copper than forages. Most forages provide 3 or 4 times the copper requirement of beef cattle. Plants that contain high levels of molybdenum, sulfur, phytate, or lignin may reduce copper absorption (Underwood, 1977). In regions where copper-deficient soils exist, if soil molybdenum levels are high or if plant sources of copper are in chemical forms that are unavailable to the animal, copper supplementation may be necessary. Chapman and Bell (1963) ranked inorganic forms of copper in decreasing order of availability as CuCO_3 , $\text{Cu}(\text{NO}_3)_2$, CuSO_4 , CuCl_2 , Cu_2O , CuO (powder), CuO (needles), and Cu (wire).

Iodine

Iodine (I) is present in most cells of the body. Inorganic iodine is taken up by the thyroid gland for the synthesis of thyroid hormones. Thyroid hormones have an active role in thermoregulation, intermediary metabolism, reproduction, growth and development, circulation, and muscle function. Dietary organic iodine is degraded to more usable inorganic forms before being absorbed. In nonruminants, dietary inorganic iodine is absorbed along the gastrointestinal tract and transported by loose attachment to plasma proteins (Underwood, 1977). In ruminants the rumen is the primary absorption site, while the abomasum aids in excretion of iodine (Barua et al., 1964). After absorption, iodine is distributed throughout the body. Of a total of 50 mg of iodine in the human body, 10 to 15 mg are located in the thyroid gland (Harper et al., 1979).

Concentrations of iodine in the thyroid vary with the amount of iodine intake, age, and gland activity. Iodine stored in the thyroid exists in several forms: inorganic iodide, mono and diiodotyrosine, thyroxine, triiodothyronine, and thyroglobulin. Eighty percent of hormonal iodine stored by the thyroid is thyroxine (T_4); the balance is in the form of transition products. Accumulation of inorganic iodine and conversion of transition products to thyroxine is completed over a 48-hour period. Kidney and skeletal muscle also contain large proportions of total body iodine. In the female, iodine concentrations in ovaries are 3 to 4 times that of muscle (Gross, 1962). Small amounts of iodine found in bile, hair and skin, stomach, and mammary glands act as storage sites that may endogenously supply the body with iodine when the need exists. Two-thirds of ingested inorganic iodine is excreted by the kidney. The level of urinary iodine is positively correlated with plasma iodine concentration and dietary uptake.

Milk may also be considered a form of iodine secretion. The amount of iodine in milk is influenced by iodine intake, season, level of milk production, and use of iodine disinfectants. Hemken et al. (1972) fed 0, 6.8, or 68 mg of potassium iodide daily to lactating dairy cows; the resulting milk contained 0.008, 0.081, and 0.694 ppm of iodine. Average iodine content of milk from 111 herds was 0.646 ppm with a range of 0.04 to 4.84 ppm (Hemken, 1978). High levels of iodine in milk are the result of either feeding high levels of dietary iodine or use of iodine as a sanitizing agent. Udder washes caused the iodine content of milk to increase by an average of 0.035 ppm (Conrad and Hemken, 1975). Colostrum contains twice as much iodine as milk during midlactation.

Deficiencies of iodine may occur when animals con-

sume feeds grown on iodine-deficient soils. In the United States the Northwest and Great Lakes regions are recognized as iodine-deficient areas. Samples of hay from Maryland farms contained 1.31 to 2.54 ppm iodine, while those from Illinois contained 0.62 to 1.02 ppm iodine (Hemken et al., 1972). Signs of an iodine deficiency include goiter, hairlessness in the young, retarded growth and maturity, lowered metabolic rate, and increased water retention. In some cases the deficient condition does not originate from a deficient diet but is caused by the presence of dietary substances that affect thyroid function and/or iodine uptake. Underwood (1977) reported interrelationships that interfere with iodine metabolism as (1) thiocyanates, perchlorate, and rubidium salts; (2) high dietary arsenic, fluorine, or calcium levels; (3) deficient or high cobalt levels; and (4) low manganese intakes. Soybean meal and cottonseed meal have both been shown to have goitrogenic effects by increasing serum thyroxine losses to the intestinal tract (Miller et al., 1972).

Cattle requirements for iodine have not been extensively studied. The estimated iodine requirement for a 500-kg cow is about 1 mg per day. A normal diet for a lactating cow provides 3.5 to 5 times this amount.

Iodine toxicity has been studied in many animals. Symptoms of iodine toxicity include anorexia, coma, death, and necrosis of kidney, liver, and mucosal linings of the gastrointestinal tract.

Calves with an initial weight of 100 kg were fed calcium iodate to provide dietary levels of 10 to 200 ppm iodine (Newton et al., 1974). Diets containing iodine in excess of 50 ppm depressed growth rate and feed intake. Calves fed diets with added iodine had increased adrenal weights, but no consistent iodine effect on the weight of thyroid glands was observed. It was concluded that 50 ppm iodine was the minimum toxic level for calves. Yearling heifers suffered depressed daily gains when fed a level of 435 ppm iodine, but additions of 71, 140, or 283 ppm iodine to their diets had no effect on daily gains (Fish and Swanson, 1977). Lactating cows fed diets with 200 ppm iodine [from ethylenediamine dihydriodide (EDDI)] for 49 weeks exhibited no changes in thyroid or pituitary function (Convey et al., 1977). Providing iodine, as EDDI, at levels of 2.5 mg/kg of body weight to pregnant cows had no effect on the cow or her unborn calf. Levels of 5 to 7.5 mg/kg of body weight increased the incidences of premature births and weak and abnormal calves at birth and the number of stillbirths.

Feed additives that supply iodine include calcium iodate, cuprous iodide, ethylenediamine dihydriodide, potassium iodate, potassium iodide, sodium iodate, sodium iodide, and pentacalcium periodate.

The most convenient and widely used method of supplementing the diet with iodine is the use of iodized salt. Problems with iodine deficiency in cattle should not occur if iodized salt blocks are not weathered and iodine is administered at proper levels. Biological availability of iodine supplements was reviewed by Ammerman and Miller (1972) and Miller et al. (1975) studied metabolism of iodine from several sources.

Iron

Iron (Fe) has important biochemical functions in animals since it is a component of hemoglobin, myoglobin, cytochrome, and the enzymes catalase and peroxidase. The iron in these materials exists in porphyrin rings. Because it is an integral part of these materials, iron is involved in the transport of oxygen to cells as well as cellular respiration. In cattle a majority of body iron is in the form of hemoglobin, with lesser amounts existing as protein-bound stored iron, myoglobin, and cytochrome. The spleen contains iron in high concentrations, with lower levels found in the liver, kidney, and heart (Standish et al., 1969).

Iron may be absorbed from all sections of the small intestine, but the principal site of absorption is the duodenum. The percentage of dietary iron that is absorbed is low in animals that have normal iron status but is increased in animals deficient in iron. Ferrous iron is absorbed to a much greater extent than ferric iron. Reduction of ferric to ferrous iron occurs in the small intestine.

Loss of iron from the body is low and occurs in urine, feces, sweat, dermis, and blood (Dubach et al., 1955). Hemorrhage may represent a severe loss of iron and greatly increases the requirement.

Iron requirements of ruminants are not well established. However, it is understood that young animals have higher iron requirements than adults. Based on research by Bremner and Dalgarno (1973) and Matrone et al. (1957) and the summary by the NRC (1978), the iron requirements of calves are thought to be about 100 ppm, while 50 ppm appears adequate for older cattle.

Iron deficiencies are most likely to occur in young animals (with high iron requirements) that are fed milk diets (milk contains less than 10 ppm iron) and in animals with excessive blood loss. Signs of a lack of iron include hypochromic microcytic anemia (reduced hemoglobin, reduced packed cell volume), reduced saturation of transferrin, listlessness, pale mucus membranes, reduced appetite and weight gain, and atrophy of the papillae of the tongue (Blaxter et al., 1957; Thomas, 1970; Bremner and Dalgarno, 1973).

Iron toxicity is characterized by reduced feed intake and reduced daily gain and by increased hemosiderin

contents of reticulo-endothelial cells and of parenchymal cells of liver, kidney, and spleen (siderosis). Diarrhea, hypothermia, and metabolic acidosis are also observed. Physiological lesions include vascular congestion of liver, kidney, heart, lungs, brain, spleen, and gastrointestinal tract (NRC, 1980). Minimum toxic levels of iron have been reported to be as low as 1000 ppm and as high as 2500 ppm (Hartley et al., 1959; Standish et al., 1969, 1971; Koong et al., 1970; Standish and Ammerman, 1971). An iron level of 1000 ppm is given by the NRC (1980) as the maximum tolerable level for cattle. This is higher than the iron contents of most feedstuffs.

Iron contents of common feeds are: forages, 100 to 500 ppm; cereal grains, 30 to 80 ppm; oilseed meals, 100 to 400 ppm; meat and fish meals, 400 to 600 ppm; and calcium and phosphorus mineral supplements, 40 to 7000 ppm. Much of the variation in iron contents of feeds is likely due to contamination during manufacture or sample preparation. Ammerman et al. (1967) ranked iron sources in decreasing order of availability, as ferrous sulfate, ferrous carbonate, ferric chloride, and ferric oxide. Thompson and Raven (1959) and Raven and Thompson (1959) reported that iron in grasses and legumes was less available than in ferric chloride.

Magnesium

Magnesium (Mg) is the fourth most abundant cation in the body. It is required for skeletal development as a constituent of bone; it plays an important role in neuromuscular transmission and activity; and it is required to activate many enzyme systems by forming a metal-enzyme complex. Enzymes requiring magnesium include those that split and transfer phosphate groups; this includes both phosphates and enzymes concerned in reactions involving ATP. Since ATP is required in many metabolic reactions, it can be inferred that the action of magnesium also extends to these reactions. Magnesium is also required as a cofactor in decarboxylation and an activator of many peptidases (Wacker and Vallee, 1964).

Approximately 65 percent of total body magnesium is contained in bone. One-third of magnesium in bone is combined with phosphorus, and the remainder is adsorbed loosely on the surface of the mineral structure. The remaining 35 percent is distributed among various tissues and organs. Normal plasma magnesium levels range from 1.8 to 2.0 mg/100 ml (Underwood, 1966), with values below 1.0 to 1.2 mg/100 ml indicative of magnesium deficiency.

Absorption of magnesium occurs prior to the intestines (Grace et al., 1974; Greene et al., 1983), from the small intestine (Field, 1961) and some from the large

intestine (Smith, 1962; Care and Van't Klooster, 1965). Excretion of endogenous magnesium is primarily via feces. However, urine is considered the major disposal route for magnesium absorbed in excess of requirements (Rook et al., 1958).

Magnesium requirements of young calves have been reported to range from 12 to 30 mg/kg body weight per day (Huffman et al., 1941; Blaxter et al., 1954; Blaxter and McGill, 1956). Data are limited regarding requirements for growing and finishing cattle; however, requirements are assumed to be similar to those for calves. Beef cow requirements are between 7 and 9 g/day during gestation and 21, 22, and 18 g/day during early, mid, and late lactation, respectively (O'Kelley and Fontenot, 1968, 1969).

Magnesium requirements may be increased by feeding high levels of aluminum, potassium, phosphorus, or calcium, as these minerals decrease the efficiency of magnesium absorption and/or utilization (Wise et al., 1963; Newton et al., 1972; Greene et al., 1983). Age and magnesium status of cattle may alter requirements, since younger cattle and magnesium-deficient cattle appear to have more efficient magnesium absorption mechanisms (Smith, 1962). Beef cows with high levels of milk production also have higher magnesium requirements (Blaxter and McGill, 1956).

Deficiencies of magnesium may occur as a result of simple deficiencies, such as with young calves restricted to milk diets (Blaxter et al., 1954; Blaxter and Rook, 1954); however, deficiencies are more frequently associated with the acute metabolic disorder hypomagnesemic tetany, commonly referred to as grass tetany. Hypomagnesemic tetany is most likely to occur with beef cows during initial stages of lactation while grazing pastures containing less than 0.2 percent magnesium (Underwood, 1966). Older cattle are probably more susceptible than younger cattle because of lowered labile magnesium stores and decreased absorption efficiency (Smith, 1962; Thomas, 1965).

Magnesium-deficient cattle exhibit anorexia and reduced dry matter digestibilities (Martin et al., 1964). Deficiencies in young cattle may result in defective bones and teeth. Initial signs of magnesium deficiency include nervous apprehension, ears carried backwards, staring eyes, and an ataxic gait. As the deficiency becomes more severe, cattle become hypersensitive to tactile or sound stimuli, with muscle tremors occurring and finally giving way to convulsions. Death usually occurs during or after one of these convulsions.

Activities of many magnesium-dependent enzymes are depressed during magnesium deficiency (Moore et al., 1938; Tufts and Greenberg, 1938; Elin et al., 1971). Subnormal levels of blood magnesium are common, and clinical signs of tetany usually occur when

blood levels drop to 1.0 and 1.2 mg/100 ml (Underwood, 1966). Tissue levels of potassium decline, and calcium and sodium may rise in magnesium-deficient animals.

Magnesium toxicity does not occur in cattle fed typical rations. Supplemental levels of magnesium up to 114 g/day have been fed without affecting cattle; however, levels of 170 to 350 g have resulted in deleterious effects (Care, 1960). Maximal tolerable levels have been established as 0.4 percent of the ration by the NRC (1980). Feeding toxic levels has resulted in anorexia, reduced performance, and occasional diarrhea (Pierce, 1959). Cattle experiencing toxicity may also exhibit lack of reflexes and respiration depression. Plasma and urinary magnesium levels are highly correlated with magnesium intake (above requirements) and are useful in detecting toxicity.

Commonly used feedstuffs vary widely in magnesium concentration and availability. Magnesium contents of most cereal grains are between 0.12 and 0.18 percent. Protein supplements of animal origin are low in magnesium, while those of plant origin usually contain 0.3 to 0.6 percent. Magnesium contents of herbage plants vary greatly and are normally higher in legumes than grasses. Magnesium fertilization usually increases plant magnesium content. Also, magnesium availability increases with increasing plant maturity (Underwood, 1966).

Several sources of inorganic magnesium may be used to supplement cattle. Magnesium carbonate, oxide, and sulfate are considered good sources of supplemental magnesium; however, magnesium from magnesite and dolomite limestone is not readily available to cattle (Gerken and Fontenot, 1967; Ammerman and Chicco, 1968).

Manganese

Manganese (Mn) is nutritionally essential for both plants and animals. Deficiencies of manganese lead to degenerative reproductive failure in both males and females, bone malformations and crippling, ataxia, depigmentation, and deterioration of the central nervous system. Manganese is a preferred metal cofactor for many enzymes involved in carbohydrate metabolism and in mucopolysaccharide synthesis. Manganese enzyme systems include glycosyltransferase, pyruvate carboxylase, GTP oxaloacetate carboxylase, isocitrate dehydrogenase, malic dehydrogenase, arginine synthetase, and glutamine synthetase. A large number of enzyme systems that require magnesium can utilize manganese. Manganese (+2) may also replace zinc (+2) in zinc-dependent enzymes, but this usually reduces the catalytic properties.

All ruminant tissues contain manganese in low concentrations. The glandular organs that are most sensitive to manganese status are liver, kidney, pancreas, and pituitary, and they exhibit the highest manganese content, with a measureable amount found in bone (Hidiroglou, 1979). The liver contains important mobilizable manganese stores. Bentley and Phillips (1951) measured liver stores of manganese at 12 ppm (DM basis) when cattle were fed dietary manganese at 30 ppm.

Ruminants regulate manganese levels in blood and tissues via homeostatic control of intestinal absorption. Manganese is excreted via feces, with little in urine. Bertinchamps et al. (1966) concluded that bile was the principal route of manganese excretion. Phosphorus, calcium, iron, zinc, copper, magnesium, and molybdenum have been implicated as interacting with manganese. Work by Hidiroglou et al. (1978) and Lassiter et al. (1972) suggests a calcium-phosphorus-manganese interaction.

Requirements for manganese are increased by elevated dietary levels of calcium and phosphorus (Hawkins et al., 1955; Lassiter et al., 1972); thus, establishment of a single requirement value is difficult and may be misleading. Also, only limited information is available concerning manganese requirements of ruminants. Mature females have higher requirements for manganese than feedlot cattle because of an increased need for reproduction and fetal development (Bentley and Phillips, 1951; Rojas et al., 1965). Dyer et al. (1964) noted that cows fed diets with 56 ppm of manganese had normal calves, but those fed diets with 47 ppm manganese and a high level of calcium gave birth to deformed calves. The manganese requirement of 40 ppm given by Hidiroglou (1979) and the NRC (1978) should be adequate for normal reproduction, but 20 ppm is likely to be adequate for growing-finishing cattle (Underwood, 1977).

Hidiroglou et al. (1978) listed the average plasma manganese value for cattle as 25 ng/ml. According to Leach (1971), there are at least two manganese-dependent enzyme systems that are severely affected by manganese deficiency, resulting in skeletal and postural defects. These are the polymerase system, which is responsible for chain elongation of polysaccharides, and the galatoseyltransferase system, which links protein molecules with polysaccharides. Chondroitin sulfate is the mucopolysaccharide most severely affected by a lack of manganese, thus affecting synthesis of bone connective tissue.

Impairment of reproductive function in males and females occurs during manganese deficiency. Along with impaired spermatogenesis (Underwood, 1977), irregular or absent estrus, and delayed conception, Utter (1976) and Hidiroglou et al. (1978) noted that manga-

nese is known to be an activator of numerous enzymes, including hydrolases, kinases, decarboxylases, and transferases. Inhibition of these enzyme systems could result in insufficient material for fetal growth and, therefore, may contribute to abortion and deformities. Hidiroglou and Shearer (1976) reported a high manganese content of corpora lutea, suggesting another possible role for manganese in normal reproduction. For males, manganese deficiency is demonstrated by impaired spermatogenesis; testicular and epididymal degeneration; sex hormone inadequacy; and, eventually, sterility.

For ruminants, manganese is among the least toxic of the required minerals. There are few documented toxicities. At 125 ppm manganese, hemoglobin levels are depressed, and anemia occurs in growing pigs. Supplementation with iron overcomes the hemoglobin depression at 125 ppm manganese. When 1250 ppm manganese was fed, growth of pigs was irreversibly depressed (Matrone et al., 1959). The manganese-iron antagonism also is suggested to occur in cattle.

Ruminants fed diets with 1000 ppm manganese have near normal growth rates and feed intakes and do not exhibit obvious indications of toxicity. Cunningham et al. (1966) noted a significant depression in blood hemoglobin as levels of a dietary manganese were elevated above 1000 ppm. The NRC (1980) states that with a balanced diet about 1000 ppm is the maximal tolerable level on a short-term basis for sheep and cattle, with about 2000 ppm the maximum level for poultry and only 400 ppm for swine.

Manganese levels in pastures, grains, and forages are variable because of variations in plant species, soil types, soil pH, and fertilization practices. Forages contain high levels of manganese, with a grass-legume forage approaching levels of 100 ppm (DM basis), while such grains as corn, barley, and oats contain from 15 to 40 ppm manganese (Redshaw et al., 1978; Hidiroglou, 1979).

Molybdenum

Molybdenum (Mo) is found in nearly all body cells and fluids, but its essentiality is due to its biochemical role in the enzymes xanthine oxidase, aldehyde oxidase, and sulfide oxidase. These metallo-enzymes contain molybdenum, as well as FAD, and are involved in the oxidation of purines and reduction of cytochrome C. Xanthine oxidase, which contains both molybdenum and copper, is involved in the reduction of iron (3+ ferritin to 2+ ferritin) and iron metabolism (De Renzo et al., 1953; Mahler et al., 1954; Seelig, 1972).

Most of the molybdenum in the body is found in skeletal muscle, with lesser quantities found in liver, muscle,

kidneys, skin, wool, and hair. Dick (1956) reported data that showed about 2 percent of body molybdenum is in liver. Molybdenum contents of soft tissue, blood, and milk are affected by molybdenum intake and are also greatly affected by copper and sulfur intakes.

Hexavalent molybdenum, such as that in sodium and ammonium molybdates, is well absorbed by cattle. Molybdenum in forages also is readily absorbed and may interfere with copper metabolism in cattle. The molybdenum from dried forage may not be as available as that from green forage, since forages that interfere with copper metabolism when grazed do not cause difficulties when fed as dry forage. Absorption of molybdenum is from the intestine, and excretion of molybdenum is primarily via urine, with small amounts excreted in bile and milk.

Requirements for molybdenum are not established. An exact estimate of the molybdenum requirement is impossible since copper and sulfate alter molybdenum metabolism. Furthermore, the majority of research on molybdenum has concentrated on the interrelationship with copper and sulfate, rather than on a specific requirement. Ward (1978) speculated that there is no safe dietary level of molybdenum because of such interactions. Work by Ellis et al. (1958) with growing lambs showed faster gains when dietary molybdenum was increased from 0.36 to 2.37 ppm.

Molybdenum and sulfur both interfere with copper metabolism, and several mechanisms have been proposed to explain these interrelationships. Dowdy and Matrone (1968a,b) used sheep, pigs, and chickens to substantiate the existence of a copper-molybdenum complex and to verify the antagonistic action of molybdenum on copper metabolism. These workers concluded that excess molybdenum may cause a copper deficiency as a result of the formation of absorbable, but metabolically unavailable, copper-molybdate complex. The molar ratio of copper to molybdenum in the complex was about 4:3. The complex formed optimally at a neutral pH and contained no sulfur. This complex may explain certain instances where plasma copper levels have been normal but where copper deficiency signs have been observed.

Sulfur, in the absence of molybdenum, also may cause a copper deficiency because of the formation of insoluble, unabsorbed copper sulfide in the gut. Rumen microorganisms rapidly convert sulfate and other sulfur-containing compounds to sulfide, providing conditions favorable for the formation of unavailable copper sulfide.

Sulfide also may be absorbed and form copper sulfide in the body. Sulfide oxidase, an enzyme that liberates copper from copper sulfide, is inhibited by molybdenum. Thus, molybdenum may contribute to a copper deficiency by preventing the liberation of copper from

copper sulfide in the body. Plasma copper levels would remain normal, but the animal would be copper deficient.

The combined effects of dietary sulfur and molybdenum on copper status are synergistic. This may be due to the formation of unabsorbable copper thiomolybdate (Huisings et al., 1973; Dick et al., 1975; Suttle, 1975). The formation of copper sulfide and copper thiomolybdate would greatly reduce copper absorption, since both render copper unavailable. Thus, plasma and liver copper levels are reduced and symptoms of copper deficiency develop. Likewise, blood levels of molybdenum decline and fecal excretion increases. The formation of copper sulfide, copper molybdate, and copper thiomolybdate (one or more of which may occur under specific conditions) can explain most observations of the copper-sulfur-molybdenum interrelationship. The formation of copper sulfide and copper thiomolybdate in the digestive tract explains those instances where molybdenum or molybdenum and sulfur caused decreased absorption of copper and decreased blood and liver copper. Formation of copper molybdate, which is absorbed but not utilized, explains those instances where blood copper levels are elevated and liver copper remains normal but the animal exhibits signs of copper deficiency.

Clinical signs of molybdenum toxicity in cattle are diarrhea, anorexia, anemia, ataxia, and bone malformation. Depigmentation of skin and hair, with a loss of crimp in wool, are the clinical signs exhibited by sheep. Signs of molybdenosis are similar to those of a copper deficiency.

Molybdenum levels of 5 to 6 ppm inhibit copper storage and produce signs of molybdenosis (NRC, 1980). Elevated dietary copper alleviates the toxic effects of molybdenum (Ferguson et al., 1943; Miller and Engel, 1960; Mills, 1960; Ward, 1978). When added to experimental diets, molybdenum has been supplied as sodium or ammonium molybdate.

Phosphorus

Phosphorus (P) has varied, but extremely important, biochemical and physiological roles. It is deposited in bone as calcium hydroxy appetite $[\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2]$. Phosphorus is a component of phospholipids, which influence cell permeability and are components of myelin sheathing of nerves. Many energy transfers in cells involve the high-energy phosphate bonds in ATP. Phosphorus plays an important role in blood buffer systems. Activation of several B-vitamins (thiamin, niacin, pyridoxine, riboflavin, biotin, and pantothenic acid) to form coenzymes requires their initial phosphorylation. Phosphorus also is a part of the genetic materials DNA and RNA.

Normal blood plasma phosphorus levels vary from 4 to 8 mg/100 ml. Erythrocytes contain much more phosphorus than does plasma; thus, whole blood contains 6 to 8 times as much phosphorus as does plasma. A major fraction of total body phosphorus is found in bone. Phosphorus is also found in high concentrations in brain, muscle, liver, spleen, and kidneys.

Like calcium, phosphorus absorption is an active process. Sodium may be required for the absorption of phosphorus (Taylor, 1974), and the process is stimulated by 1,25-dihydroxy cholecalciferol (Chen et al., 1974). The amount of phosphorus absorbed is dependent on source, intestinal pH, age of the animal, and dietary levels of calcium, iron, aluminum, manganese, potassium, magnesium, and fat (Irving, 1964). Excess phosphorus is excreted primarily in the feces.

Methods employed to establish phosphorus requirements and discussion of these values relative to published data are presented in the Calcium section earlier in this chapter.

High iron levels result in the formation of insoluble iron phosphate, resulting in low phosphorus rickets (Underwood, 1977). Aluminum also forms insoluble, unavailable phosphates.

Because many forages contain inadequate levels of phosphorus to meet the requirements of growing or lactating cattle (Black et al., 1943), and because phosphorus-deficient soils are common, phosphorus deficiencies in cattle are widespread. Also, mature forages and crop residues generally contain low levels of phosphorus (Maynard et al., 1935), while the cereal grains and oilseed meals contain moderate to high levels of phosphorus. A deficiency of phosphorus results in decreased growth rates, inefficient feed utilization, and a depraved appetite (chewing of food, soil and bones, a condition termed pica). Anestrus, low conception rate, and reduced milk production are frequently associated with low-phosphorus diets. However, Teleni et al. (1977) suggested that reproductive difficulties in beef cows may be more related to protein intake. Plasma phosphorus levels decline during phosphorus deficiencies. Phosphorus-deficient animals may have weak, fragile bones and become stiff in the joints (Preston et al., 1977).

High phosphorus intakes may cause bone resorption, elevated plasma phosphorus levels, and urinary calculi as a result of precipitation of calcium and magnesium phosphates in the kidney. Feeding increased amounts of calcium may reduce the incidence of urinary calculi in animals fed high phosphorus diets (Emerick and Embry, 1963, 1964).

In a review of availabilities to ruminants of phosphorus compounds, Peeler (1972) ranked availabilities of common sources of phosphorus as follows: dicalcium

phosphate, defluorinated phosphate and bone meal, and soft phosphate. Sodium phosphates and ammonium polyphosphate are approximately equal to dicalcium phosphate in phosphorus availability. Orthophosphates are more available than meta and pyrophosphates. Oilseed meals and animal and fish products are feeds that contain large amounts of phosphorus. Phytate phosphorus is not well utilized by nonruminants, but ruminants appear to use considerable quantities of this form of phosphorus (McGillivray, 1974).

Potassium

Potassium (K) is the third most abundant mineral element in the animal body and the principal cation of intracellular fluid; it also is a constituent of extracellular fluid, where it influences muscle activity. Red blood cells contain approximately 25 times as much potassium as is present in plasma. Muscle and nerve cells also are high in potassium, containing over 20 times that present in interstitial fluids.

The concentration of potassium in the fat-free body of adult cattle is 78 mEq/kg (Wilde, 1962). Serum potassium concentrations in cattle are about 4.7 mEq/l (Welt et al., 1960).

Several studies have been conducted to determine potassium requirements of cattle. Variable values have been reported: the discrepancies possibly depend on amounts needed for only maintenance or for maintenance plus optimum growth or to effects of potassium on digestive function. Roberts and St. Omer (1965) concluded that the dietary potassium requirement of finishing steers was between 0.5 and 0.6 percent of the ration. A low potassium basal ration (0.08 percent potassium) was supplemented with K_2CO_3 to provide rations containing 0.36, 0.50, 0.67, or 0.77 percent potassium (Devlin et al., 1969). This trial indicated that the potassium requirement for finishing steers was higher than 0.51 percent but not above 0.72 percent of the diet. Clanton (1980) suggested that the potassium requirement of pregnant beef cows is between 0.5 and 0.7 percent. The requirement for potassium is higher for ruminants than for nonruminants.

Low serum potassium (hypokalemia) may be caused by malnutrition, negative nitrogen balance, gastrointestinal losses, and endocrine malfunction. Sex and age differences in potassium concentrations may be related to physiological aging or to the ratio of muscle mass of other body constituents (Welt et al., 1960). Signs of hypokalemia include anorexia, weight loss, muscle weakness, irritability, paralysis, and tetany. Evaluation of a potassium deficiency is difficult. Serum analyses were of little use in a trial with feeder lambs (Telle et al., 1964). Reduced feed consumption appears to be an early sign of

inadequate dietary potassium. Changes in electrocardiogram and muscle potassium content have been used with limited success to diagnose potassium deficiency. Because reliable evaluations of a potassium deficiency are not available, dietary potassium concentration appears to be the best indicator of potassium status.

High serum potassium is not likely to occur under normal situations. If extracellular potassium is increased from 5 to 10 mEq/l, toxicity may result (Wilde, 1962). After periods of moderately high potassium intake, animals can survive potassium intakes that would otherwise be lethal (Wright et al., 1971). High dietary levels of potassium interfere with magnesium absorption in ruminants and can cause hypomagnesemic tetany in sheep (Newton et al., 1972; Fontenot et al., 1973). Increasing the potassium level in a liquid diet from 1.2 to 5.8 percent, dry basis, resulted in the death of 3 of 8 calves (Blaxter et al., 1960). Jackson et al. (1971) noted reduced weight gains as the potassium contents of diets for lambs were increased from 0.7 to 3.0 percent. The clinical signs before death were cardiac insufficiency, edema, muscular weakness, and loss of muscular tone. No abnormalities in magnesium metabolism were observed. Increasing dietary magnesium levels may offer protection against potassium toxicity.

Livestock needs for potassium vary with amounts of protein, phosphorus, calcium, and sodium consumed. Forage crops are high in potassium, even though their potassium contents depend on the fertility of the soil in which they are grown. Diets based largely on milo, corn, or corn and cob meal, together with low-potassium hays and silages, may fall short in providing sufficient potassium for fast-growing or high-producing animals. Most high-protein feeds contain high levels of potassium. Also, Clanton (1980) has shown that beef cows grazing standing forage during winter months may be deficient in potassium. The most common source of supplemental potassium is KCl.

Selenium

Selenium (Se) is similar to sulfur in its chemical properties. Interest in the biological significance of selenium was initially confined to the problem of toxicity in animals (Underwood, 1971; Ulrey, 1973).

In 1973, glutathione peroxidase was shown to be a seleno enzyme (Rotruck et al., 1973); it contains four selenium atoms (Briggs and Calloway, 1979). Sulfur-containing amino acids serve as precursors for glutathione and are therefore necessary for proper glutathione peroxidase function (Burk, 1976). It is postulated that glutathione peroxidase prevents membrane damage because of its antioxidant property (Hoekstra,

1973). Any postulates concerning the biochemical role of selenium must consider the interrelationship between selenium and vitamin E (Hoekstra, 1973). It has been conclusively shown that selenium cannot be completely replaced by vitamin E, but their functions intertwine to account for their mutual sparing effect. Selenium is also effective in reducing cadmium and mercury toxicity (Parizek et al., 1973).

Absorbed selenium is carried in the plasma (associated with protein) until it enters tissues (Moxon and Rhian, 1943; Herrman and McConnell, 1973). Selenium is excreted in feces and urine; however, fecal excretion is greater than urinary excretion in ruminants (McConnell, 1941; Underwood, 1971). Pulmonary excretion of selenium is an important excretory route when dietary intakes are high (McConnell, 1942; McConnell and Portman, 1952; Ganther et al., 1966); however, it is insignificant, at least in the rat, when dietary selenium is less than 1 ppm (Burk et al., 1972).

The selenium requirement of beef cattle depends on the amount of vitamin E in the diet, but ranges are suggested as follows: growing and finishing steers and heifers, 0.10 mg/kg dry weight diet; breeding bulls and pregnant and lactating cows, 0.05 to 0.10 mg/kg dry weight diet. The NRC (1980) suggested that 0.10 to 0.30 mg/kg dry weight of diet met requirements and that 2 mg/kg dry weight diet is the maximum tolerable level for all species.

Minimum requirements of animals vary with the form of selenium ingested and the nature of the diet, especially vitamin E content (Underwood, 1971). Selenium is found associated with dietary protein as selenoamino acids in plants (Olson et al., 1970). Selenium in animal feeds is highly variable primarily due to the selenium status of the soil (Underwood, 1971). The plant species *Astragalus* and *Stanleya*, selenium accumulators that grow mainly in seleniferous areas, can contain between 1000 and 3000 ppm selenium. Thus, grazing livestock may be adversely affected (Underwood, 1971; Briggs and Calloway, 1979).

White muscle disease, a selenium-responsive myopathy, is characterized by white muscle, heart failure, and paralysis (lameness, to an inability to stand) (Whanger et al., 1973). It is a muscular dystrophy that cannot be produced in calves on vitamin E-free diets unless the diets are high in unsaturated fats (Muth et al., 1958; Hartley and Grant, 1961). Depression of glutathione peroxidase in tissues of selenium-deficient animals may account for many of the manifestations of selenium deficiency.

Selenium was identified as a toxicant in studies begun in 1929 (Franke, 1934). General signs of toxicity include loss of appetite, loss of tail hair, sloughing of hoofs, and

eventual death (NRC, 1980). Death is the result of respiratory failure along with starvation and thirst. Two types of selenium poisoning have been observed: acute, "blind staggers"; and chronic, "alkali disease" (Rosenfeld and Beath, 1964). Toxicity varies with the amounts and chemical form of selenium ingested, the duration and continuity of intake, and the nature of the diet (Underwood, 1971). Edible herbage in seleniferous areas contains 5 to 20 ppm (Underwood, 1971). Tissue levels increase with toxic intakes to a point; then excretion begins to keep pace with absorption and further accumulation does not occur (Underwood, 1971). High-protein diets and arsenic also appear to offer some protection (Levander and Baumann, 1966; Underwood, 1971) against high selenium intakes.

Sodium and Chlorine

Sodium (Na) functions in maintaining osmotic pressure, acid-base balance, and body-fluid balance. This cation is also involved in nerve transmission and active transport of amino acids. Sodium is required for cellular uptake of glucose through activation of the glucose carrier protein. Chlorine (Cl) is necessary for the activation of amylase and is essential for formation of gastric hydrochloric acid. In respiration and regulation of blood pH, chlorine is transferred between plasma and erythrocytes through a process known as the chloride shift.

Sodium is the major cation of extracellular fluid and provides a majority of the alkaline reserve in plasma. The sodium content of plasma is normally 140 mEq/l. Much of the body's sodium is incorporated into crystals in bone, where it is not released until bone is resorbed. Thus, this fraction may serve as a slowly available sodium pool.

Chlorine is usually studied with sodium, as it is the major anion of the extracellular fluid. Plasma chlorine concentration is normally 107 mEq/l, which is slightly less than sodium concentration. Less than 15 percent of body chlorine is found within cells.

Sodium and chlorine are mainly absorbed from the proximal portion of the small intestine, but they may also be absorbed from the distal section of the small intestine and the large intestine. Some absorption of sodium and chlorine may occur from the rumen.

Carnivorous animals usually secure adequate sodium and chlorine in their diets. However, herbivores require supplementation, because plant materials are usually low in sodium and high in potassium. Potassium may promote sodium excretion (Hafez and Dyer, 1969).

In domestic animals, deficiencies of sodium and chlorine may occur because plants have low-sodium contents, because sodium losses caused by perspiration may

occur in animals maintained in warm environments or used for hard work, and because sodium needs increase during lactation and during periods of rapid growth (Hafez and Dyer, 1969; Underwood, 1970).

Sodium requirements are generally met by supplemental sodium chloride. It is readily available and is low in cost. This, in part, may account for the lack of published requirements for chlorine in beef cattle. Sodium concentrations of 0.06 to 0.08 percent of diet dry matter for nonlactating yearlings and calves and no more than 0.1 percent dry matter for lactating beef cows (Morris and Gartner, 1971; Morris and Murphy, 1972; Morris, 1980) have been found to meet requirements. Burkhalter et al. (1979) reported that young bulls fed diets with 0.038 percent chlorine had gains and intakes that were similar to those for young bulls fed diets that contained 0.5 percent chlorine.

Animals can be maintained for some time on low-sodium diets because of their efficient conservation mechanisms. In severe deficiencies, animals may experience muscle cramps and a craving for salt that is evident through constant licking, general weakness, and death (Hafez and Dyer, 1969). Other signs may include weight loss, decrease in milk production, and rough hair coat (Underwood, 1970).

Most animals can tolerate large quantities of dietary salt when an adequate supply of water is available (NRC, 1980). More dramatic effects of sodium toxicosis may occur if the animal's water is contaminated with dissolved salts. Addition of sodium chloride to drinking water to give 12 to 20 g/l caused anorexia, decreased water consumption, weight loss, elevated plasma potassium and sodium concentrations, depressed plasma magnesium and urea levels, and physical collapse in cattle (Weeth et al., 1960; Weeth and Haverland, 1961).

Much of the western half of the United States, and many other semiarid regions, have soils that are high in salinity and saline groundwater, which may lead to saline water intoxication. Clinical signs follow consumption of water that has more than 7000 ppm of dissolved salt and include low consumption of feed and water, mild digestive disturbances, low rates of gain, and diarrhea (Jensen and Mackey, 1979).

Sodium and chlorine are widely distributed in nature; however, feedstuffs used in livestock production contain insufficient salt to meet requirements. Meyer et al. (1950) reported sodium and chlorine contents for several feeds.

Sulfur

Sulfur (S) is a component of protein, some vitamins, and several important hormones. Common amino acids

that contain sulfur are methionine, cysteine, and cystine. Amino acid derivatives that contain sulfur include cystathionine, taurine, and cysteic acid. Methionine is a key amino acid, since all other sulfur compounds, except the B-vitamins thiamine and biotin, that are necessary for normal body function can be synthesized from methionine. Body functions that involve sulfur include protein synthesis and metabolism, fat and carbohydrate metabolism, blood clotting, endocrine function, and intra- and extracellular fluid acid-base balance (Baker, 1977).

Sulfur has both structural and metabolic functions; thus, it is found in virtually every tissue and organ of the body. Masters and McCance (1939) showed that muscle has a fairly constant nitrogen to sulfur ratio of 15.3:1. The total body content of sulfur is approximately 0.15 percent.

The microbial population of the rumen has the ability to convert inorganic sulfur into organic sulfur compounds that can be utilized by the animal. Block et al. (1951) concluded that sodium sulfate was converted in the rumen to cystine and methionine and then incorporated into microbial protein. The use of elemental sulfur by microbes has been demonstrated by Saville et al. (1975). The availability of sulfur to rumen microbes from different sources, organic and inorganic, has been ranked from most to least available by Kahlon et al. (1975) as L-methionine, calcium sulfate, ammonium sulfate, DL-methionine, sodium sulfate, sodium sulfide, elemental sulfur, and hydroxy analog of methionine.

Most diets that are fed to cattle contain adequate amounts of sulfur to meet the animal's needs, but in certain feeding regimes, supplementation with sulfur has proven beneficial. Cattle fed high-grain rations that were supplemented with nonprotein nitrogen responded to the addition of elemental sulfur (Meiske et al., 1966). Rees et al. (1974) fed cattle pangola grass and increased dry matter intakes and digestibilities when either the grass was fertilized or supplemented with sulfur.

Requirements of beef cattle for sulfur are not well defined. Most research to determine sulfur requirements of ruminants has been conducted using sheep and lactating dairy cows, both of which produce products with higher sulfur contents than do beef cattle. A diet that contained 0.106 percent sulfur met requirements of 5- to 11-week-old calves (Leibholz, 1972). The beef cow, whether in gestation or lactation, is thought to have sulfur requirements that are similar to those of finishing cattle.

The interrelationship between copper, molybdenum, and sulfur has received wide attention. Copper requirements are increased by both sulfur and molybdenum.

Copper forms cupric sulfide, which is insoluble in all parts of the digestive tract. Cupric molybdate may also be formed. Cupric molybdate can be absorbed but is metabolically inactive (Dowdy and Matrone, 1968a,b). A third compound that reduces the availability of copper is unabsorbable copper thiomolybdate (Huisings et al., 1973; Diek et al., 1974).

The interrelationship between selenium and sulfur is due in part to their similar structures. Selenium can replace sulfur in some organic compounds, but the metabolic activity of the seleno-compound is less than that of the normal sulfur-containing compound (Diplock, 1976). Selenium toxicity can be counteracted by the feeding of sulfur, but the form of the sulfur is a major factor. Whanger (1970) showed that selenium absorption was decreased by sulfur compounds with the most influence being exhibited on seleno-compounds by its sulfur analog.

Signs of sulfur deficiency include reduced appetite, weight loss, weakness, excessive salivation, watery eyes, dullness, emaciation, and death (Thomas et al., 1951; Starks et al., 1953; Whanger, 1968). In a sulfur deficiency, microbial protein synthesis is reduced, and the animal shows signs of protein malnutrition. A lack of sulfur also results in a microbial population that does not utilize lactate; therefore, lactate accumulates in the rumen, blood, and urine (Whanger and Matrone, 1966, 1967). Serum sulfate levels have been suggested as an indicator of sulfur deficiency (Weir and Rendig, 1952), but blood lactate and dietary sulfur levels may be the most reliable indicators of sulfur status (Goodrich et al., 1978).

Sulfur toxicity is characterized by restlessness, diarrhea, muscular twitching, dyspnea, and in prolonged cases by inactivity followed by death (Coghlin, 1944). The cause of these signs of toxicosis is thought to be sulfide, which is produced in large quantities when high-sulfur rations are fed (Bray, 1969). Since sulfate may be absorbed readily throughout the digestive tract, excesses may lead to metabolic acidosis. The suggested maximum level for sulfur in the diet is 0.4 percent (NRC, 1980), but Boucharad and Conrad (1976) suggested a lower level (0.26 percent) for lactating dairy cows.

All feeds contain some sulfur, but the amount usually depends on the protein content of the feed. Feeds higher in protein will usually have more sulfur. Availability of the sulfur in the feed to microbial reduction in the rumen may be of as much concern as the actual amount that is present.

Zinc

Zinc (Zn) has been recognized as an essential element for animals since 1935 (Bertrand and Bhattacharjee,

1935). Requirements for zinc are based on its biochemical function as both an activator and constituent of several dehydrogenases, peptidases, and phosphatases that are involved in nucleic acid metabolism, protein synthesis, and carbohydrate metabolism (Vallee, 1959; Underwood, 1956; Hsu and Anilare, 1966; Mills et al., 1969).

Zinc concentration in the body of cattle is approximately 30 ppm. Zinc is found in high concentrations in soft tissues such as the pancreas, liver, pituitary gland, kidney, and adrenal gland. Bone, teeth, hair, and the choroid and iris of the eye are also high in zinc content. In males, testicles and accessory sex glands have high zinc concentrations. Normal plasma zinc levels range from 80 to 120 μg per 100 ml, with one-third of the zinc firmly bound to globulin and the remainder loosely bound to albumin (Vallee, 1962).

Absorption of zinc occurs primarily from the abomasum and lower small intestine, with little zinc absorbed below the cecum (Miller and Cragle, 1965). Feces is the primary route of zinc excretion. Little zinc is excreted in urine (Feaster et al., 1954). Fecal zinc includes unabsorbed zinc, zinc secreted into the gut, zinc from bile and pancreatic secretions, and zinc from desquamated epithelial cells.

Zinc requirements of cattle are not precisely defined. Results of several trials suggest requirements to be between 20 and 40 mg/kg diet dry matter (Miller et al., 1962, 1963; Mills et al., 1967). In other trials, feeding higher levels improved performance (Perry et al., 1968).

Requirements may be altered by dietary levels of cadmium, calcium, iron, magnesium, manganese, molybdenum, and selenium since these minerals affect zinc absorption and/or utilization (Van Campen and Mitchell, 1965; Holod et al., 1969; Van Campen, 1969; Suttle and Field, 1970; Ivan and Grieve, 1975). Requirements vary according to age and growth rate, since zinc absorption decreases with age and as growth rate decreases (Stake et al., 1973). Beef cows with high levels of milk production have higher requirements, since milk contains 300 to 500 mg of zinc per liter.

Zinc deficiencies have been reported in ruminants grazing forages low in zinc or high in compounds interfering with zinc utilization (Pierson, 1966; Mayland, 1975). Deficiencies are characterized by decreased performance and listlessness, followed by development of swollen feet and a dermatitis that is most severe on the neck, head, and legs. Deficiencies may also result in vision impairment, excessive salivation, decreased rumen, volatile fatty acid production, and a failure of wounds to heal normally (Miller et al., 1965; Ott et al., 1965; Pierson, 1966; Mills et al., 1967). Impaired reproductive performance may occur in zinc-deficient bulls and cows (Pitts et al., 1966).

Readily available stores of zinc are small, and deple-

tion is reflected by a rapid drop in liver and plasma zinc. Deficiencies are difficult to detect in early stages or in milder forms. Biochemical changes with promising diagnostic value are declines in zinc concentration in plasma, hair, and tissue. However, perhaps the best indicator is increased feed intake and growth after feeding supplemental zinc, since deficient cattle respond rapidly to supplemental zinc (Miller and Miller, 1962; Mills et al., 1967).

The extent of zinc tolerance is dependent on the diet, particularly concentrations of minerals that affect zinc absorption and utilization. Therefore, the threshold for zinc toxicity cannot be adequately defined. Steers have been fed diets containing 1000 ppm zinc for 13 to 18 months without marked reduction of performance (Feaster et al., 1954).

Plant species vary widely in zinc concentration, with legumes usually having higher concentrations than grasses. In general, most hays and silages contain less than 60 ppm zinc. Cereal grains normally contain between 10 and 30 ppm zinc. Protein supplements of plant origin contain 50 to 70 ppm zinc, and those of animal origin contain 90 to 100 ppm zinc. Sources of inorganic zinc that may be used to supplement cattle include acetate, carbonate, chloride, and sulfate and metallic zinc (NRC, 1980).

VITAMINS

Cattle have physiological requirements for most vitamins required by other mammals. Furthermore, calves from adequately fed mothers have minimal stores of vitamins at birth. Synthesis by microorganisms in the rumen, supplies in natural feedstuffs, and synthesis in tissues meet most of the usual requirements. Colostrum is rich in vitamins, providing immediate protection to the newborn calf. The ability to synthesize B vitamins and vitamin K in the rumen develops rapidly when solid feed is introduced into the diet. Vitamin D is synthesized by animals exposed to direct sunlight and is found in large amounts in sun-cured forages. High-quality forages contain large amounts of vitamin A precursors and vitamin E.

Vitamin A

The vitamin A requirements for beef cattle are 2200 IU per kilogram of dry feed for feedlot cattle; 2800 IU per kilogram for pregnant heifers and cows, and 3900 IU per kilogram for lactating cows and breeding bulls (Jones et al., 1938; Guilbert and Hart, 1935; Guilbert et al., 1940; Madsen et al., 1948; Church et al., 1956; Chapman et al., 1964; Cullison and Ward, 1965; Perry

et al., 1965, 1968; Swanson et al., 1968; Kohlmeier and Burroughs, 1970; Meacham et al., 1970; Kirk et al., 1971; Eaton et al., 1972). These requirements are the same as those given in the fifth edition of this report (NRC, 1976). An IU is defined as 0.300 μg of vitamin A alcohol (retinol) or 0.550 μg of vitamin A palmitate. Efficiency of conversion of carotenoids to retinol is variable in beef cattle and generally lower than that for nonruminant animals (Ullrey, 1972). One milligram of β -carotene is assigned a value of 400 IU (2.5 μg β -carotene per IU). While it is common for commercial formulators to add a safety factor to these values, general practical experience with them has been satisfactory, although systematic experimental reevaluations have not been attempted.

Vitamin A is the vitamin most likely to be of practical importance in feeding cattle. Although the only well-established biochemical function of vitamin A is its role as a component of the visual purple required for dim-light vision, it is essential for normal growth, reproduction, and maintenance of healthy epithelial tissue. Vitamin A activity is supplied in natural feeds mainly by carotenoid precursors. High-quality forages provide carotenoids in large amounts but tend to be quite seasonal in availability. Few grains, except for yellow corn, contain appreciable amounts of carotenoids. Carotene is rapidly destroyed by exposure to sunlight and air, especially at high temperatures. Ensiling effectively preserves carotene, but the availability of carotene from corn silage may be low (Jordan et al., 1963; Smith et al., 1964; Miller et al., 1967).

The liver can store large amounts of vitamin A. These stores serve to prevent vitamin A deficiency during periods of suboptimal intake. Unfortunately, liver stores are highly variable and cannot be assessed accurately without taking samples by biopsy. The duration of protection afforded by liver stores can vary from none to perhaps a year or longer. Intakes necessary to establish and maintain these stores are considerably greater than the listed requirements. The stores are in a dynamic state (Frey and Jensen, 1947; Hayes et al., 1967), but factors influencing deposition and removal are not well understood. On a practical basis it is seldom safe to expect more than 2 to 4 months of protection from stored vitamin A, and cattle should be observed carefully for signs of deficiency whenever the diet is deficient.

Dietary vitamin A deficiency is most likely to occur when cattle are fed (1) high-concentrate diets; (2) bleached pasture or hay grown under drought conditions; (3) feeds that have had excess exposure to sunlight, air, and high temperature; (4) feeds that have been heavily processed or mixed with oxidizing materials such as minerals; and (5) feeds that have been stored for

long periods of time. Newborn calves deprived of colostrum and cattle that have been prevented from establishing or maintaining good liver stores through exposure to drought, winter feeding without high-quality forage, or exposure to stresses such as high temperature or elevated nitrate intake are particularly susceptible. Deficiencies can be corrected by increasing carotene intake through the introduction of high-quality forage or by supplying vitamin A in the feed or by injection. Since inefficient conversion of carotene to vitamin A is often a part of the problem, administering preformed vitamin A is preferred when deficiency signs are present. Injected vitamin A is used more efficiently than oral vitamin A (Perry et al., 1967; Schelling et al., 1975), possibly because of extensive destruction of dietary vitamin A in the rumen and abomasum (Keating et al., 1964; Klatte et al., 1964; Mitchell et al., 1967).

Signs of vitamin A deficiency include reduced feed intake, rough hair coat, edema of the joints and brisket, lacrimation, xerophthalmia, night blindness, slow growth, diarrhea, convulsive seizures, improper bone growth, blindness, low conception rates, abortion, stillbirths, blind calves, abnormal semen, reduced libido, and susceptibility to respiratory and other infections (Guilbert and Hart, 1935; Jones et al., 1938; Guilbert et al., 1940; Guilbert and Rochford, 1940; Hart, 1940; Madsen and Earle, 1947; Madsen et al., 1948; Moore, 1957; Mitchell, 1967). Only nyctalopia has proven unique to vitamin A deficiency (Moore, 1939, 1941). Vitamin A deficiency should be suspected when several of these symptoms are present. Clinical verification may include ophthalmoscopic examination, liver biopsy and assay, blood assay, testing spinal fluid pressure, conjunctival smears, and response to vitamin A therapy.

The possibility that β -carotene may have a role in reproduction independent of its role as a vitamin A precursor has received considerable recent attention (Hemken and Bremel, 1982). Evaluation of these reports and their potential practical significance will remain difficult until a biochemical function is proposed for carotene and either verified or rejected.

Vitamin D

The vitamin D requirement of beef cattle is 275 IU per kilogram of dry diet. The IU is defined as 0.025 μg of cholecalciferol (D_3) or its equivalent. Ergocalciferol (D_2) also is active in cattle. Beef cattle exposed to sunlight or fed sun-cured forages rarely require vitamin D supplementation.

Vitamin D is required for calcium and phosphorus absorption, normal mineralization of bone, and mobilization of calcium from bone. Research in laboratory an-

imals (DeLuca, 1974) indicates that before serving these functions it must be metabolized to active forms. One metabolite (25-hydroxy-vitamin-D₃) is formed in the liver and is about four times as active as vitamin D. Another metabolite (1,25-dihydroxy-vitamin-D₃) formed in the kidney is about five times as active as 25-hydroxy-vitamin-D₃. Extension of observations on these metabolites to cattle and study of other metabolites unique to ruminants are being actively pursued (Horst and Reinhardt, 1983) and can be expected to add much to our understanding of vitamin D nutrition. Degradation of vitamin D in the rumen (Parakkasi et al., 1970; Sommerfeldt et al., 1979) may be of practical significance when considering methods of vitamin D administration.

The best defined sign of vitamin D deficiency in calves is rickets, which involves failure of bone to mineralize adequately. Accompanying signs frequently include decreases in calcium and inorganic phosphorus in blood, swollen and stiff joints, anorexia, fast breathing, irritability, tetany, weakness, convulsions, and retarded growth. In older animals with a vitamin D deficiency, bones become weak and easily fractured, and posterior paralysis may accompany vertebral fractures. Calves may be born dead, weak, or deformed (Rupel et al., 1933; Wallis, 1944; Warner and Sutton, 1948; Stallings et al., 1964).

Vitamin E

The vitamin E requirement has not been clearly established but is estimated to be between 15 and 60 IU per kilogram of dry diet for young calves. The IU is defined as 1 mg of dl- α -tocopherol acetate. Normal diets apparently supply adequate amounts for adult cattle. Even diets very low in vitamin E did not affect growth, reproduction, or lactation when fed for four generations (Gullickson and Calverley, 1946).

Vitamin E is an antioxidant and has been widely used to protect and to facilitate the uptake and storage of vitamin A (Perry et al., 1968). Its action in metabolism is not clearly defined but is linked closely with selenium (Muth et al., 1958; Hoekstra, 1975). Some deficiency signs, particularly white muscle disease, may respond to either selenium or vitamin E or may require both. Vitamin E and selenium interactions are discussed in the Selenium section. Deficiencies may be precipitated or accentuated by feeding unsaturated fats. Signs of deficiency in young calves are characteristic of white muscle disease. They include general muscular dystrophy, weak leg muscles, crossover walking, impaired suckling ability due to dystrophy of tongue muscles, heart failure, and paralysis (Stafford et al., 1954; Muth et al., 1958).

Vitamin K

Vitamin K₁ is abundant in pasture and green roughages. Vitamin K₂ is synthesized in large amounts in the rumen. Either effectively fulfills the vitamin K role in the blood clotting mechanism. The only practical deficiency to be reported in cattle is the "sweet clover disease" syndrome. This results from the antagonistic action of dicoumarol that is formed in moldy sweet clover hay. Dicoumarol leads to prolonged blood clotting times and has been responsible for animal death from uncontrolled hemorrhages. Mild cases can be treated effectively with vitamin K (McElroy and Goss, 1940a; Link, 1959).

B Vitamins

Deficiency signs have been clearly demonstrated for thiamine (Johnson et al., 1948), riboflavin (Wiese et al., 1947), pyridoxine (Johnson et al., 1950), pantothenic acid (Sheppard and Johnson, 1957), biotin (Wiese et al., 1946), nicotinic acid (Hopper and Johnson, 1955), vitamin B₁₂ (Draper et al., 1952; Lassiter et al., 1953), and choline (Johnson et al., 1951) in young calves. Most of the established metabolic functions of B vitamins are important to cattle as well as to other animals. Consequently, a physiological need for most B vitamins can be assumed for cattle of all ages. However, B vitamins are abundant in milk and many other feeds, and synthesis of B vitamins by ruminal microorganisms is extensive (McElroy and Goss, 1940a,b, 1941a,b; Wegner et al., 1940, 1941; Hunt et al., 1943) and begins very soon after the introduction of dry feed into the diet (Conrad and Hibbs, 1954). As a result, practical B-vitamin deficiency is limited to situations where an antagonist is present or ruminal synthesis is limited by lack of precursors or other problems.

Vitamin B₁₂ is of special interest because of its role in propionate metabolism (Marston et al., 1961) and the practical incidence of vitamin B₁₂ deficiency as a secondary result of cobalt deficiency. Substantial areas of the United States, Australia, and New Zealand have soils without enough cobalt to produce adequate levels in plants to support optimum vitamin B₁₂ synthesis in the rumen (Ammerman, 1970). This is discussed in more detail in the section on cobalt.

Thiamin antimetabolites have been found in raw fish products and bracken fern (Somogyi, 1973). More recently (Loew and Dunlop, 1972; Sapienza and Brent, 1974), polioencephalomalacia (PEM) in grain-fed cattle and sheep has been linked to thiaminase activity or production of a thiamin antimetabolite in the rumen. Affected animals have responded to intravenous adminis-

tration of thiamin (2.2 mg/kg of body weight). Supplementation of high-concentrate diets with thiamin has yielded inconsistent results (Grigat and Mathison, 1982, 1983).

Niacin has been reported to enhance protein synthesis by ruminal microorganisms (Riddell et al., 1980, 1981). Responses to niacin additions to diets for feedlot cattle have been variable.

Attempts to obtain responses to other B vitamins are numerous, but the overall results are considered inconclusive. While B vitamin synthesis is altered by diet, considerable change is possible without producing indications of deficiency (Hayes et al., 1966; Clifford et al., 1967).

3 Water

Water intake in feeds plus that consumed *ad libitum* as free water is approximately equivalent to the water requirements of cattle. The water requirement is influenced by several factors, including rate and composition of gain, pregnancy, lactation, activity, type of diet, feed intake, and environmental temperature.

Restriction of water intake reduces feed intake (Utley et al., 1970), which results in lower production. However, water restriction tends to increase apparent digestibility and nitrogen retention.

The minimum requirement of cattle for water is a reflection of that needed for body growth; for fetal growth or lactation; and of that lost by excretion in the urine, feces, or sweat or by evaporation from the lungs or skin. Anything influencing these needs or losses will influence the minimum requirement.

The amount of urine produced daily varies with the activity of the animal, air temperature, and water consumption as well as with certain other factors. The anti-diuretic hormone, vasopressin, controls reabsorption of water from the kidney tubules and ducts; thus, it affects excretion of urine. Under conditions of restricted water intake, an animal may concentrate its urine to some extent by resorbing a greater amount of water than usual. While this capacity for concentration of the urine solutes is limited, it can reduce water requirements by a small amount. When an animal consumes a diet high in protein or salt or one that contains substances having a diuretic effect, the excretion of urine is increased and so is the water requirement.

The water lost in the feces depends largely on the diet. Succulent diets and diets with high mineral content contribute to more water in the feces.

The amount of water lost through evaporation from

the skin or lungs is important and may even exceed that lost in the urine. If temperature and/or physical activity increase, water loss through evaporation and sweating increases.

Since feeds themselves contain some water and the oxidation of certain nutrients in feeds produces water, not all must be provided by drinking. Feeds such as silages, green chop, or growing pasture forage are usually very high in moisture content, while grains, hays, and dormant pasture forage are low. High-energy feeds produce much metabolic water, while low-energy feeds produce little. These are obvious complications in the matter of assessing water requirements. Fasting animals or those on a low-protein diet may form water from the destruction of body protein or fat, but this is of minor significance.

The results of water requirement studies conducted under varied conditions imply that thirst is a result of need and that animals drink to fill this need. The need results from an increase in the electrolyte concentration in the body fluids, which activates the thirst mechanism.

As this discussion suggests, water requirements are affected by many factors, and it is impossible to list specific requirements with accuracy. However, the major influences on water intake in beef cattle on typical rations are dry matter intake, environmental temperature, and stage and type of production. Table 6 has been designed with this in mind. It is a guide only, and it must be used with considerable judgment.

For more detailed information on toxic substances in water, refer to the National Research Council publication *Nutrients and Toxic Substances in Water for Livestock and Poultry* (1974).

4

Breeding Females

Energy requirements for pregnancy have been calculated using the equation given in Chapter 6. From this equation, 2.15 Mcal extra NE_m , for example, would be required for a pregnant cow bearing a 36-kg calf during the last 94 days of pregnancy.

Since determined values for NE requirements of lactating beef female are not available, they were assumed to be similar to those determined for dairy cattle. The requirements listed in the tables for lactating cows were based on the metabolizable energy requirements for 5 and 10 kg of milk given in *Nutrient Requirements of Dairy Cattle* (NRC, 1978) and were adjusted to a comparable NE_m value assuming that the milk contains 4 percent fat. This increases the need for NE_m by 0.75 Mcal/kg of milk. Fifty-five grams per day of protein have been used as a mean rate of protein deposition in the products of conception during the last third of pregnancy, assuming a 36-kg birth weight.

NUTRIENT RELATIONSHIPS

Beef cows are managed under a variety of conditions to best utilize the feed resources available under existing environmental conditions. This variation presents a challenge in applying nutrient requirements. Since the beef cow can utilize a wide array of feed sources, production levels to optimize economic return vary depending on the feed resources. Hence, it may not be economical to feed cows to meet their nutrient requirements with all production systems.

The source of energy is generally the first consideration in determining a balanced ration for beef cows. Until the energy requirement is satisfied, protein, minerals, and vitamins may not be well utilized. The amount of energy required for different production levels will vary. Because the beef cow uses fiber as a major

source of energy, the quantity of forage or feed and the quality are important.

When energy is limited, supplemental protein will be used for energy until the energy needs are met; then the remaining protein will be used to meet the protein needs (Clanton and Zimmerman, 1970). These researchers have shown, for example, that feeding high levels of low-protein (6.7 and 7.9 percent) supplements (7.2 and 8.0 Mcal DE/day) to growing replacement heifers wintered on native grass range threatened the nutritional status of the heifers. Protein was the limiting nutrient; thus, the extra supplemental energy provided no increase in weight gain; in fact, there was a decrease. When the added energy contained 13 or 16 percent protein, heifers gained weight. This demonstrated that protein, not energy, limited performance. These same relationships can be demonstrated using other nutrients. The proper relationships are difficult to establish because the quantity and quality of the diet selected by grazing animals are difficult to assess.

COW EFFICIENCY

Much consideration has recently been given to the effect of cow size on energy requirements for efficient calf production. Anderson (1983) calculated the energy requirements for different-sized cows for maintenance, weight change, and milk production and showed that changes in cow size and weight did not affect the efficiency of milk production. Small and large cows were equally efficient. Therefore, it may be more important to feed cows on the basis of potential milk production rather than size and condition. Data collected by Lemenager et al. (1980) suggest that weight alone cannot be used to accurately determine the energy requirements of the breeds of heavier weight or greater poten-

tial milk production. Visual body condition score combined with weight predicted the relative total digestible nutrient (TDN) requirements of pregnant cows during late gestation more accurately than do weight and milk production alone. Maintenance energy requirements of cows may be influenced by milk production potential as well as body size.

WEIGHT CHANGES AND BODY CONDITION

Aside from weight loss at parturition, weight change in a mature cow reflects body condition change (loss or gain of body fat). Weight change can be measured accurately, whereas the number scoring system (1 = thinnest and 9 = fattest) for condition change is empirical and subject to judgment. More accurate procedures are available for measuring body composition, but their use is generally limited to experimentation.

In the bred heifer, weight change is a combination of growth and condition change. This makes nutrient requirements more difficult to assess. A thin heifer needs to gain more weight during gestation than one that has a moderate or fat condition. This gain is necessary for continued growth and rebreeding in the minimum time. Condition cannot be determined by weight alone because heifers of different frame sizes differ in weight at the same condition. Condition must be considered in nutrient requirements for bred heifers.

When mature cows lose condition from inadequate energy intake prior to calving, the interval from calving to first estrus will be lengthened, resulting in calving intervals exceeding 1 year (Wiltbank et al., 1962). Inadequate energy intake after calving will lower conception rates (Wiltbank et al., 1962, 1964). The same effect has been demonstrated with bred yearling heifers (Clanton and Zimmerman, 1970; Bellows and Short, 1978). It appears desirable to have cows gain an amount of weight the last trimester equal to the weight lost at calving. This is even more important with the replacement heifer. Weight gain will not necessarily reflect increased condition. Condition is often lost prior to calving. Weight gain between calving and breeding is desirable and will improve conception rates, resulting in a shorter calving interval. Phillips and Vavra (1981) showed that cows losing weight (18 kg) the last trimester of pregnancy had as short an interval from calving to first estrus as those that gained weight (48 kg) during that period (58 versus 56 days). Both groups lost weight from calving until breeding, but there was no difference in conception rates (86 versus 84 percent, respectively) in a 60-day breeding season. Those that gained weight prior to calving lost the most weight after calving. One might have

expected a higher conception rate had they gained weight following calving. Many cows do not gain weight between calving and breeding yet maintain acceptable conception rates. Cows need to be in good condition prior to calving to do this. It is costly to have cows gain weight following calving because it generally requires feeding of supplemental energy and protein. The small increase in production may not offset the increase in cost. If cows can be placed on new growth pasture forage 3 to 4 weeks prior to the breeding season, they will start gaining weight and show improved reproductive performance (Clanton et al., 1971).

Cows in good condition are more tolerant to the stresses of winter and require less maintenance energy per unit of weight than do cows in poor condition (Thompson et al., 1983). Klosterman et al. (1968) established a relationship between the height at the hooks and the weight of a cow that can be used to adjust energy requirements for cows in different conditions. The average weight (kg) to height (cm) ratio for a cow in good condition is 4.0:1. The adjustment in digestible energy (DE) required by mature cows in different condition can be determined using the following formula: $(4.0 - \text{weight/height}) \times 1.716 = \text{Mcal/day adjustment}$. Clanton and Zimmerman (1970) have shown that changes in wither height and heart girth circumference along with weight change can be used to separate growth from change in condition of bred heifers.

In many range areas or during periods of feed scarcity, lactating and breeding females frequently lose weight during part of the year. Weight may be regained during periods of more abundant feed. Cyclic loss and gain of weight may not be detrimental to overall calf production, depending on the length and severity of the poor feed conditions and the physiological status of the animals. Calf production should be greater if condition did not cycle, but preventing condition changes may not be economically feasible. The requirements listed in the tables for lactating and breeding females need to be adjusted according to previous or anticipated feed availability and the economics associated with management of a particular enterprise.

Weight loss at parturition should be considered when using the requirement tables. A 500-kg cow in the last third of pregnancy will weigh less later when she is lactating. Weight of the cow in early pregnancy should be used for the cow for the entire year.

FORAGE INTAKE

Several factors that alter voluntary intake should be considered in the nutrition program for beef cows. Rumen capacity, as demonstrated by Campling and Balch

(1961), and low digestibility and rate of passage (Campling et al., 1961; Conrad et al., 1964) limit forage intake. Forage availability, use of supplements, and climatic conditions also affect intake. Other influencing factors include animal size, milk production, and reproductive status.

The range in voluntary intake of organic matter by cattle grazing native winter range forage in the Central Great Plains is 45 to 60 g/kg $W^{0.75}$ (Rittenhouse et al., 1970; Scales et al., 1974; Yates et al., 1982). In contrast, organic matter intake of native summer range forage in the same region varies from 70 to 85 g/kg $W^{0.75}$ daily (Streeter et al., 1968; Powell et al., 1982; Yates et al., 1982). Forage intake of grazing cattle is reduced if quantity or quality of pasture is not adequate (Johnstone-Wallace and Kennedy, 1944; Hennessy and Robinson, 1979; Holloway et al., 1979). In meeting nutrient requirements of grazing cattle, the condition of the range or pasture and the amount of available forage present must be considered.

Certain supplements to low-quality forage may decrease forage intake (Forbes et al., 1967; Lusby et al., 1976; Rittenhouse et al., 1970; Scales et al., 1974; Umoh and Holmes, 1974). Other supplements increase forage intake (Campling et al., 1962; Blaxter and Wilson, 1963; Clanton and Zimmerman, 1970). The primary difference in the intake response appears to be associated with the protein content of the forage and the amount of supplement fed. If the forage is low in protein, forage intake will increase when a small amount of a high-protein supplement is fed. But when more than 1 kg of supplement is fed, forage intake could be reduced by displacement.

Forage intake of grazing cattle can be greatly reduced by short periods of cold weather with snow cover (Rittenhouse et al., 1970); yet this is a time when more energy is needed to meet increased maintenance requirements (NRC, 1981). Supplemental forage or concentrate feeding should be given during such times to avoid large losses of weight.

Pregnant cows nearing parturition consume 12 to 13 percent less feed than nonpregnant cows (Campling, 1966; Jordan et al., 1973). Consumption increases rapidly following parturition. If forage quality is low, supplementing with higher-quality forage or with concentrates prior to parturition may be necessary to compensate for reduced feed intake.

Dry matter intake of beef cows is extremely variable. Daily intakes of lactating cows have ranged from 4.5 to 14.5 kg (Johnstone-Wallace and Kennedy, 1944). Quantity and quality were the major factors influencing intake. Lactating (spring calving) or gestating (fall calv-

ing) cows grazing crested wheat grass pasture during the summer in Oregon had similar intakes, 11.39 versus 11.37 kg daily (Kartchner et al., 1979). This was 3.0 and 2.8 percent of their spring body weight, respectively. Lactating cows were 34 kg lighter at the start of the grazing season. Holloway et al. (1979) observed that Angus cows that were nursing calves and grazing Kentucky-31 tall fescue (*Festuca arundinacea* Schreb) in the summer consumed 10.5 kg of dry matter per day when it had a high quality (70 percent digestible) and 8.8 kg when it was of poor quality (58 percent digestible).

Streeter et al. (1974) measured milk production and forage intake of Brown Swiss, Charolais x Angus, and Hereford cows grazing irrigated mountain meadow. Dry matter consumptions were 14.7, 12.0, 10.4 kg per head per day, respectively. Milk production in a 14-hour period was 6.0, 4.4, and 3.5 kg, respectively. Likewise, Lusby et al. (1976) found that Hereford, Hereford x Holstein, and Holstein cows fed a 1.22-kg supplement per day while nursing calves on dry winter range consumed 78, 104, and 131 g of dry matter daily per kilogram $W^{0.75}$, respectively. Daily dry matter intake during summer grazing without a supplement was 99, 107, and 144 g/kg $W^{0.75}$, respectively.

Daily dry matter intake of lactating cows was 121.3 g/kg $W^{0.75}$ in May and 97.4 g/kg $W^{0.75}$ in July when grazing Midland Bermudagrass (*Cynodon dactylon*) at El Reno, Oklahoma (Horn et al., 1979). This equates to daily intakes of 2.6 and 2.1 percent of body weight, respectively, for cows weighing 454 kg. Similar intakes (99 g/kg $W^{0.75}$) were observed by Lusby et al. (1976) with lactating Hereford cows grazing native range in June. These cows had received 1.11 kg supplements daily during the previous winter while grazing similar range forage. Cows fed 2.41 kg supplements during the winter consumed 84 g/kg $W^{0.75}$ of forage dry matter the following June, indicating possible carryover effects. On the same range, Lemenager et al. (1978) measured dry matter intake of 105 g/kg $W^{0.75}$ with nonpregnant Hereford cows during the winter.

Daily forage dry matter intake of mature Hereford cows grazing native Flint Hills pasture in Kansas ranged from 8.1 kg (1.7 percent of fall weight) in November to 16.8 kg (3.45 percent of fall weight) in June (Pruitt, 1980). Winter supplementation programs did not affect subsequent forage intake.

Feed intake of beef cows is difficult to predict because of the many variable factors, including animal, diet, and environmental stress. Dry matter intakes in the tables should be used as a guide and adjusted for specific conditions.

5 Special Considerations

PROCESSING FEEDSTUFFS

Many methods are used to improve the nutritive value of feedstuffs for beef cattle. The purpose of this section is to define major effects of processing on their nutritive value for beef cattle rather than on the methods per se. Reviews of the methods are provided in the references.

Roughages

Coarse chopping of long roughages, with or without wafering, does not affect nutritive value substantially and is recommended primarily to improve handling (Minson, 1963). In contrast, fine grinding of long roughages, which is usually followed by pelleting, increases feed intake by 50 percent or more (Greenhalgh and Wainman, 1972). Larger responses in intake through grinding and pelleting are associated with poorer-quality roughages and with diets where roughage is the major constituent. Furthermore, grinding and pelleting of roughage increase its intake more in young cattle than in older cattle. Grinding and pelleting of roughages depress their digestibility, by up to 5 percentage units. Digestibility is depressed most when intake of the processed material is high and when the roughage processed is grass (Campling and Milne, 1972). In contrast to depressing digestibility, grinding and pelleting improve utilization of the digestible energy, so that net energy per unit weight of the processed material exceeds the corresponding unprocessed roughage (Greenhalgh and Wainman, 1972). This effect is partly due to processing causing a higher percentage of the roughage to be digested posttruminally. When artificially drying roughages, care should be exercised to avoid the browning reaction, which renders some of the protein indigestible (Goering, 1976).

In North America, many crops are preserved by ensiling. This practice may depress voluntary intake relative to other methods of preservation, such as drying, but it has a small effect on digestibility and utilization of digested energy (McDonald and Edwards, 1976). In dry and poorly packed silage, heating may depress protein digestibility (Thomas et al., 1972). Processing of forages prior to ensiling can influence nutritional value. Intake of grass silage chopped to 20 mm may be greater than the intake of unchopped material (Murdoch, 1965), and corn silage harvested at a theoretical cut of 12.7 mm or less was more digestible than corn silage chopped at a longer length (Sudweeks et al., 1979).

Alkali treatments of crop residues and wastes have been researched and reviewed (Homb et al., 1977; Kernan et al., 1977; Jackson, 1978; Sundstel et al., 1978; Klopfenstein et al., 1979). The effectiveness of alkali treatment depends on the residue or waste being treated and the technique. Results vary substantially. Treatment with alkali increases potential digestion of cell walls. Although rates of digestion in the rumen are not altered substantially, rates of passage of indigestible material are improved (Berger et al., 1979; Coombe et al., 1979; Oji et al., 1980). Hence, voluntary intake of low-quality roughages can be improved by up to 50 percent through alkali treatment (Horton, 1978; Coombe et al., 1979; Garrett et al., 1979; Horton and Steacy, 1979; Morris and Mowat, 1980; Saenger et al., 1982). These studies have also demonstrated that digestibility of dry matter or energy may be increased by up to 10 percentage units. In diets containing 72 percent straw, NE_m was increased from 0.62 to 1.03 Mea/kg and NE_g from 0.22 to 0.51 Mea/kg through alkali treatments (Garrett et al., 1979). Improvements in intake and digestibility may be small when treated straws constitute 50 percent or less of the diet (Garrett et al., 1979). The efficacy of treating straw with alkali depends on the va-

riety of cereal from which the straw was derived (Horton and Steacy, 1979), with greatest improvements in digestibility obtained for wheat straws, followed by barley and oats. The improvement in intake through chemical treatment may be small when treated roughage is compared with untreated roughage in the ground and pelleted form (Coombe et al., 1979; Horrisberger et al., 1979). Alkali treatment, through its heating effect, depresses the nitrogen digestibility by ruminants, even when ammonia is used (Garrett et al., 1979; Horton and Steacy, 1979; Morris and Mowat, 1980; Oji et al., 1980). Since energy availability in the rumen is enhanced by alkali treatment, supplementation of treated roughages with more extensively degraded protein sources is usually beneficial.

Grains

INTRODUCTION

Many factors other than processing have a bearing on the nutritive value of grains and may modify the effects of processing. High intakes reduce digestibility. For example, the metabolizable energy of corn grain for dairy cows was reduced from 3.58 Meal/kg at a maintenance level of feeding to 2.92 Meal/kg at 2.5 times maintenance (Moe and Tyrrell, 1979). Source of grain also may have a major impact on digestibility. For example, the net energy of bird-resistant sorghum has been found to be considerably less than regular sorghum grain (Maxson et al., 1973), whereas waxy sorghum has a higher net energy (Sherrod et al., 1969). Within varieties of the same grain, total digestible nutrients (TDN) were found to vary by 7 percentage units (Parrot et al., 1969). Effect of processing may be less pronounced when available energy in the unprocessed grain is relatively high or when feed intake is relatively low. Since younger cattle can digest unprocessed grain better than older animals (Morgan and Campling, 1978), processing of grain should benefit the nutritive value of rations for yearling steers more than for calves less than a year old. Finally, response to processing grain depends on the level of roughage in the diet, and relevant details are presented for individual grains.

CORN

In rations containing at least 80 percent dry corn grain, equivalent DE and NE values have been reported whether the corn has been cracked, ground, or fed whole (Goodrich and Meiske, 1966; Vance et al., 1970, 1972; Preston, 1975). Steam processing and flaking increased net energy by at least 10 percent, in comparison to whole corn, when the diets incorporated inert rough-

ages, but was without effect in an all-corn diet (Vance et al., 1970). With corn diets containing intermediate levels of roughage (20 to 35 percent), digestibility of starch in the diet was increased approximately 5 percentage units when the grain was ground or crimped as opposed to being unprocessed (Vance et al., 1972; Galyean et al., 1979). Steam processing and flaking improved energy retention in cattle from 6 to 10 percent, relative to cracked corn, when the grain was incorporated into fattening rations composed of 70 to 80 percent corn (Johnson et al., 1968). In low-roughage diets, feeding corn in the unprocessed form (whole corn grain) maximizes intake and facilitates cattle management. Steam processing and flaking should also maximize intake in diets containing either low or intermediate levels of roughage. Generally, with diets containing more than 35 percent roughage, digestibility of the corn is positively associated with fineness of grind, so that finely ground corn contains 10 percentage units more digestible energy than whole corn (Moe and Tyrrell, 1977, 1979). Feeding of corn in a fine form in these rations, however, can be detrimental to utilization of the roughage portion of the diet (Moe et al., 1973; Ørskov, 1976, 1979) and may make these diets unpalatable. Thus, fine grinding should be restricted to maximize the nutritive value of the entire diet. Coarse grinding is most desirable to combine favorable digestion of the corn and maintain nutritive value of the roughage.

In many areas of North America, corn is preserved wet as high-moisture grain. Digestible dry matter and energy of rations containing high-moisture corn are at least equal and may be as much as 5 percentage units higher than the same ration containing dry ground corn (McCaffree and Merrill, 1968; McKnight et al., 1973; Tonroy et al., 1974; Galyean et al., 1976; Macleod et al., 1976). These results are also evident for dry corn reconstituted with moisture and stored for a short period of time before feeding (Tonroy et al., 1974). One detriment to the nutritive value of high-moisture corn is that reduced dry matter intakes of diets containing this form of corn have been observed (Clark, 1975). This is most evident when the corn contains more than 30 percent moisture. A minor concern about high-moisture corn is that most, if not all, of its vitamin E may be lost during storage (Young et al., 1975).

SORGHUM

In low-roughage (<20 percent) diets, steam processing and flaking have been shown to improve DE and TDN by 5 to 10 percentage units (Husted et al., 1968; Buchanan-Smith et al., 1968) and starch digestibility from 3 to 5 percentage units (McNeill et al., 1971; Hinman and Johnson, 1974). An important criterion for

success in steam processing and flaking is to generate a density of 2.5 kg/hl (25 lb/bushel) or slightly less than one half that of the original grain. Reconstitution of the whole grain with water, followed by an incubation period, and grinding can improve energy and starch digestibility to the same extent as steam processing and flaking (Buchanan-Smith et al., 1968; McNeill et al., 1971; Kiesling et al., 1973). However, steam processing and flaking may be more successful than reconstitution in promoting high intake (Franks et al., 1972). Despite favorable reports on the feeding value of steam-processed, flaked sorghum grain, relative to dry processing methods (Newsom et al., 1968; Franks et al., 1972), steam processing and rolling did not improve net energy of sorghum grain relative to dry grinding (Garrett, 1965). It has been reported that the NE_m and NE_g values for sorghum were both increased by 8 percentage units through fine grinding as opposed to coarse rolling; thus, fine grinding may improve the value of sorghum to an extent comparable to steam processing and flaking (Brethour, 1980). In intermediate- and high-roughage diets, dry-rolled sorghum is better utilized than in low-roughage diets (Keating et al., 1965). Thus, it is unlikely that steam processing and flaking will have beneficial effects in these circumstances. The nutritive value of dry sorghum grain in low-roughage diets may be improved by heat treatments, other than steam processing and flaking, such as popping, micronizing, exploding, and roasting (Hale and Theurer, 1972). Micronizing and popping of sorghum grain can improve digestibility of starch to an extent similar to steam processing and flaking (Riggs et al., 1970; Hinman and Johnson, 1974; Croka and Wagner, 1975). These treatments may not be as successful as steam processing and flaking for promotion of high intake of low-roughage diets.

BARLEY

Grinding or rolling improves the digestibility and utilization of barley. NE_m values of ground barley ranging from 1.69 to 1.89 Meal/kg and NE_g values from 1.03 to 1.39 Meal/kg in all-concentrate and 25 percent roughage diets have been reported (Suleiman and Mathison, 1979). No benefit for steam processing and flaking of barley, versus dry rolling, were demonstrated in one experiment (Parrot et al., 1969). To maximize intake and minimize digestive disturbances such as bloat, it is recommended that in high- or all-concentrate diets, barley be fed with medium grind to avoid fines (Hironaka et al., 1979). High-moisture barley can have a nutritive value for cattle comparable to the dry ground or rolled form. It is also recommended that high-moisture barley be medium rather than fine grind to reduce the proportion of fines.

OATS

Although whole oats may be better utilized by cattle than whole barley (Morgan and Campling, 1978), rolling or grinding improves its utilization also.

WHEAT

Whole wheat may be efficiently utilized by cattle (Trowbridge and Moffett, 1933), but its nutritive value is improved by processing. Hale et al. (1970) reported that steam-processed and flaked wheat was well utilized by cattle provided the flakes were not thin. Fine grinding of wheat generally reduces feed intake and is extremely liable to cause acidosis, although acidosis depends on the variety of wheat fed. Garrett et al. (1966) and Garrett (1968) reported that heat treatment of wheat improved its digestibility but did not significantly improve its net energy. It can be concluded that the nutritive value of wheat is optimized by dry rolling, coarse grinding, or steam processing to produce a thick flake (Brethour, 1970).

ENVIRONMENTAL INFLUENCES ON NUTRIENT REQUIREMENTS OF BEEF CATTLE

A subcommittee of the Committee of Animal Nutrition prepared a report, *Effect of Environment on Nutrient Requirements of Domestic Animals* (NRC, 1981b), that details how requirements for beef cattle might be altered to account for environmental stresses. A summary of the report's recommendations is presented here.

First, voluntary food intake can be significantly affected by the environment, particularly with effective ambient temperatures outside the thermoneutral zone 15° to 25°C. With high temperature and humidity, intake may be depressed by up to 30 percent. The extent of this depression is positively associated with temperature and humidity. High-temperature stress will be reduced if accompanied by low humidity and/or relief through more comfortable nighttime conditions. Intake depression through elevated temperature and humidity is more severe for high-roughage as opposed to low-roughage diets. With low temperatures, intake may be increased by up to 30 percent. The extent of this increase is negatively associated with temperature. An increase in intake caused by low temperatures should be observed when cattle remain relatively dry, but extensive precipitation and muddy conditions can depress intake by up to 30 percent in both the thermoneutral zone and at lower temperatures. Intake can also become severely restricted for beef cows on range during winter. Forage

intake depressions up to 50 percent have been reported for grazing cattle following a storm period that produced cold temperatures and snow cover.

Second, availabilities of nutrients from feedstuffs can be altered by environmental temperature. Temperature and digestibility appear to be positively related. These alterations are required only for roughages because effects of temperature on digestibility of concentrates are small. DE, ME, and NE values of roughages may be modified by the following formula:

$$A = B + B(0.0010 (T - 20)),$$

where A is the value adjusted for environmental temperature, B is the unadjusted value, and T is the effective ambient temperature ($^{\circ}\text{C}$).

Third, the maintenance energy requirement of cattle should be adjusted for exposure to temperatures outside the thermoneutral zone. Adapted animals should have their requirements adjusted to allow for changes in basal metabolic rate and, possibly, for acute exposure to hot or cold. Unadapted animals should have their requirements adjusted for acute exposure to either hot or cold only. For adapted animals, maintenance energy expenditure decreases rectilinearly in association with increasing temperature. The following equation is used to express the maintenance energy requirement:

$$NE = aW^{0.75},$$

where NE is the net energy required for maintenance (Mcal/day), and W is the body weight (kg).

For animals acclimated to 20°C (thermoneutral zone), the factor a is taken as 0.077. For each degree Celsius prior to exposure to temperatures above or below 20°C , 0.0007 should be subtracted or added, respectively, to a in the above equation. Thus, for cattle with prior exposure to temperatures of 30° , 20° , 10° , and 0°C , the value a becomes 0.070, 0.077, 0.084, and 0.091, respectively. For expressing maintenance energy requirements in terms of ME or DE, tabulated values should be decreased (for heat) or increased (for cold) by 0.91 percent for each degree Celsius prior exposure above or below 20°C .

For acute heat stress, maintenance energy requirements should be adjusted according to severity. Severity may be detected by the respiration of the animal. For rapid shallow breathing the maintenance energy requirement should be increased by 7 percent, whereas for deep open-mouth panting the requirement should be increased from 11 to 25 percent.

For acute cold stress, maintenance energy expenditures should be increased according to exposure to temperatures below their lower critical temperature (LCT). Calculation of the LCT for any given animal is

complex and depends on the animal's insulation and heat production. Wind speed influences insulation and is an important environmental factor. LCT varies widely for different cattle and according to environment. For example, for a 1-week-old calf exposed to dry, low wind, the LCT is estimated at $+7.7^{\circ}\text{C}$, whereas for a yearling steer gaining 1.1 kg/day and exposed to a dry, low wind, the LCT is estimated at -34.1°C . The increase in ME required per degree Celsius below the LCT is from 1 to 3 percent. For details on calculating the increase in energy requirement due to acute cold exposure, the reader is referred to the report *Effect of Environment on Nutrient Requirements of Domestic Animals* (NRC, 1981b).

IMPLANTS AND NONNUTRITIVE FEED ADDITIVES

Melengesterol acetate (MGA) is a feed additive marketed for feedlot heifers. MGA is a progestin and acts to suppress estrus, increase gains, and improve feed efficiency with finishing heifers. Sexually mature, non-gravid heifers respond to MGA, whereas it has no effect on the performance of steers, bulls, and spayed or pregnant heifers. The approved daily feeding level is from 0.25 to 0.50 mg per head. Feeds containing MGA must be withdrawn at least 48 hours prior to slaughter.

Synovex implants are of two types. Synovex-S for steers contains 20 mg of estradiol benzoate and 200 mg of progesterone. It is approved for use in steers that weigh 182 (400 lb) to 455 kg (1000 lb). Synovex-H for use with feedlot heifers contains 20 mg of estradiol benzoate and 200 mg of testosterone. It is approved for heifers weighing 182 (400 lb) to 364 kg (800 lb). Use of these products improves rate of gain and efficiency of feed utilization. Maximum responses are obtained with a high-concentrate finishing diet. In the United States and Canada there is no withdrawal prior to slaughter.

Ralgro (Zeranol) implants are available for male and female nursing calves, grazing cattle, and cattle fed finishing diets and are not for use with breeding animals. Ralgro improves rate of gain and efficiency of feed utilization. The approved dose is 36 mg. Animals must not be implanted within 65 days of slaughter.

Estradiol is available in the United States as a timed-release implant (Compudose), active for a 200-day period. Use of this product improves rate of gain and efficiency of feed utilization by feedlot cattle. There is no withdrawal period prior to slaughter.

Antibiotics are added to diets to improve rate of gain and feed efficiency. Several antibiotics reduce the incidence of liver abscesses in cattle fed high-concentrate

diets. The level for continuous feeding is 70 to 80 mg per head per day. Antibiotics are also approved at higher levels for beef cattle for the first 14 to 28 days after transport to help control shipping fever. Antibiotics that are approved for use and restrictions to their use are listed in the Feed Additives Compendium published annually by Miller Publishing Co., Minneapolis, Minnesota, for the United States, or the Compendium of Medicating Ingredient Brochures published by Agriculture Canada for Canada.

Monensin sodium is approved for use in cattle feeds at levels between 5 and 30 g per ton of complete feed (90 percent dry matter basis) or at daily feeding levels between 50 and 360 mg per day. With feedlot cattle, monensin generally improves feed efficiency but depresses feed intake, with no effect on rate of gain. Monensin is approved for use with pasture cattle at a daily feeding level of 200 mg per day for improvement in rate of gain. Monensin alters the ratio of volatile fatty acids produced in the rumen by increasing the proportion of propionic acid. Monensin may reduce fasting heat production and may increase dietary NE_m values to a greater extent than it increases dietary NE_g values. Monensin has also been shown to increase quantities of dietary protein that escape degradation in the rumen. In addition, retention of some minerals has been increased in monensin-fed cattle. Thus, energy, protein, and mineral requirements may be modified when monensin is fed to cattle. The same probably applies to other ionophores that may be fed to cattle, but data on the

other ionophores are not available (Poos et al., 1979; Garrett, 1982; Kirk et al., 1983).

Lasalocid sodium is approved for use in cattle feeds in the United States at levels between 10 and 30 g per ton of complete feed (90 percent dry matter basis) for improvement in feed efficiency. It is approved for use at 25 to 30 g per ton for increased rate of gain.

Several products, generally classified as buffers, have been added to high-concentrate finishing diets to control low-rumen pH found when high-grain diets are fed. These products include sodium bicarbonate, dolomitic limestone, ground limestone, bentonite, and magnesium oxide. Sodium bicarbonate will apparently increase the pH of rumen contents by replacing sodium bicarbonate from saliva, which is reduced in high-concentrate rations. Sodium bicarbonate and other products may exert their beneficial effects by other methods, such as increasing rumen liquid turnover, increasing osmolality of the rumen, and increasing the pH of the lower intestinal tract. For a detailed discussion of this subject area, the reader is referred to the National Feed Ingredients Association Symposium on Buffers, Electrolytes and Neutrolytes, 1983.

The use of nonnutrient additives and implants is controlled by the Food and Drug Administration in the United States and the Food Production and Inspection Branch of Agriculture Canada. Users of controlled feed additives must follow regulations regarding their use and be aware of alterations to the regulations.

6

Prediction Equations for Estimating Nutrient Requirements and Feed Intake

ENERGY

- A. Maintenance requirements (mcal/day) of steers, heifers, bulls, and cows:

$$NE_m = 0.077 W^{0.75}$$

- B. NE_g (mcal/day) required (equivalent to RE) for empty body weight gain (EBG):

Medium-frame steer calves:

$$NE_g = 0.0635 W^{0.75} (EBG)^{1.097}$$

Large-frame steer calves, compensating medium-frame yearling steers, and medium-frame bull calves:

$$NE_g = 0.0562 W^{0.75} (EBG)^{1.097}$$

Large-frame bull calves and compensating large-frame yearling steers:

$$NE_g = 0.0498 W^{0.75} (EBG)^{1.097}$$

Medium-frame heifer calves:

$$NE_g = 0.0783 W^{0.75} (EBG)^{1.119}$$

Large-frame heifer calves and compensating yearling heifers:

$$NE_g = 0.0693 W^{0.75} (EBG)^{1.119}$$

Mature thin cows:

$$NE_g = 6.5 \text{ mcal/kg gain.}$$

- C. NE_g required for live weight gain (LWG):

Medium-frame steer calves:

$$NE_g = 0.0557 W^{0.75} (LWG)^{1.097}$$

Large-frame steer calves, compensating medium-frame yearling steers, and medium-frame bull calves:

$$NE_g = 0.0493 W^{0.75} (LWG)^{1.097}$$

Large-frame bull calves and compensating large-frame yearling steers:

$$NE_g = 0.0437 W^{0.75} (LWG)^{1.097}$$

Medium-frame heifer calves:

$$NE_g = 0.0686 W^{0.75} (LWG)^{1.119}$$

Large-frame heifer calves and compensating yearling heifers:

$$NE_g = 0.0608 W^{0.75} (LWG)^{1.119}$$

Mature thin cows:

$$6.2 \text{ mcal/kg gain.}$$

- D. Energy required for pregnancy (expressed as kcal NE_m /day):

$$NE_m = \text{calf birth weight (0.0149} \\ - 0.0000407t)e^{0.05883t - 0.0000804t^2}$$

- E. Energy required for lactation (expressed as NE_m , mcal/kg milk):

$$NE_m = 0.1 (\% \text{ fat}) + 0.35$$

- F. Estimation of empty body weight gain (EBG) from NE_g available for gain:

Medium-frame steer calves:

$$EBG = 12.34 NE_g^{0.9116} W^{-0.6837}$$

Large-frame steer calves, compensating medium-frame yearling steers, and medium-frame bull calves:

$$EBG = 13.80 NE_g^{0.9116} W^{-0.6837}$$

Large-frame bull calves and compensating large-frame yearling steers:

$$EBG = 15.40 NE_g^{0.9116} W^{-0.6837}$$

Medium-frame heifer calves:

$$EBG = 9.74 NE_g^{0.8936} W^{-0.6702}$$

Large-frame heifer calves and compensating yearling heifers:

$$EBG = 10.86 NE_g^{0.8936} W^{-0.6702}$$

G. Estimation of live weight gain (LWG) from NE_g available for gain:

Medium-frame steer calves:

$$LWG = 13.91 NE_g^{0.9116} W^{-0.6837}$$

Large-frame steer calves, compensating medium-frame yearling steers, and medium-frame bulls:

$$LWG = 15.54 NE_g^{0.9116} W^{-0.6837}$$

Large-frame bull calves and compensating large-frame yearling steers:

$$LWG = 17.35 NE_g^{0.9116} W^{-0.6837}$$

Medium-frame heifer calves:

$$LWG = 10.96 NE_g^{0.8936} W^{-0.6702}$$

Large-frame heifer calves and compensating yearling heifers:

$$LWG = 12.21 NE_g^{0.8936} W^{-0.6702}$$

PROTEIN

Factorialized Protein Requirement:

$$CP = \frac{F + U + S + G + C + M}{D \times BV \times CE}$$

CP, Crude protein, g/day

F, Metabolic fecal protein loss = 3.34% dry matter intake

U, Endogenous urinary protein loss = $2.75W^{0.5}$

S, Scurf protein loss = $0.2W^{0.6}$

G, Tissue protein deposition (in grams) = (268 - $29.4 \times$ energy content of gain, Mcal/kg) daily gain in kg

C, Conceptus, 55 g/day, last third of pregnancy
M, Milk protein production (in grams) = $33.5 \times$ milk production in kg

D, True protein digestibility = 0.90

BV, Biological value = 0.66

CE, Conversion of dietary to post-ruminal protein = 1.0

Urea Potential:

g/kg dry feed = $11.78 NE_m + 6.85 - 0.0357 CP \times DEG$ (Burroughs et al., 1975)

g/kg dry feed = $31.64 - 3.558 CP + ([945 NE_m - 887 - 179 NE_m^{0.5}])^{0.5}$ (Satter and Roffler, 1975)

CP, Crude protein (%)

NE, Net energy maintenance (Mcal/kg)

DEG, Ruminal degradation of protein (%)

Calcium and Phosphorus

Calcium, g/day = $((0.0154 (W_{kg}) + 0.071 (\text{protein gain, g/day}) + 1.23 (\text{milk/day, kg}) + 0.0137 (\text{fetal growth, g/day})) \div 0.5$

Phosphorus, g/day = $((0.0280 (W_{kg}) + 0.039 (\text{protein gain g/day}) + 0.95 (\text{milk/day, kg}) + 0.0076 (\text{fetal growth, g/day})) \div 0.85$

FEED INTAKE

Breeding Females:

Daily feed intake (kg dry matter) = $W^{0.75} (0.1462 NE_m - 0.0517 NE_m^2 - 0.0074)$

Growing and Finishing Cattle:

Daily feed intake (kg dry matter) = $W^{0.75} (0.1493 NE_m - 0.0460 NE_m^2 - 0.0196)$

NE_m , net energy maintenance (Mcal/kg diet)

Adjustments for Frame Size:

None: Medium-frame steer calf, large-frame heifer, and medium-frame bull.

+10%: Large-frame steer calf and medium-frame yearling steer.

+5%: Large-frame bulls.

10% Reduction: Medium-frame heifers.

Tables of Daily Requirements: Energy, Protein, Calcium, and Phosphorus

TABLE 1 Net Energy Requirements of Growing and Finishing Beef Cattle (Mcal/day)^a

Body Weight, kg:	150	200	250	300	350	400	450	500	550	600
NE _m Required:	3.30	4.10	4.84	5.55	6.24	6.89	7.52	8.14	8.75	9.33
Daily gain, kg	NE _g Required									
<i>Medium-frame steer calves</i>										
0.2	0.41	0.50	0.60	0.69	0.77	0.85	0.93	1.01	1.08	
0.4	0.87	1.08	1.28	1.47	1.65	1.82	1.99	2.16	2.32	
0.6	1.36	1.69	2.00	2.29	2.57	2.84	3.11	3.36	3.61	
0.8	1.87	2.32	2.74	3.14	3.53	3.90	4.26	4.61	4.95	
1.0	2.39	2.96	3.50	4.02	4.51	4.98	5.44	5.89	6.23	
1.2	2.91	3.62	4.28	4.90	5.50	6.09	6.65	7.19	7.73	
<i>Large-frame steers, compensating medium-frame yearling steers and medium-frame bulls</i>										
0.2	0.36	0.45	0.53	0.61	0.68	0.75	0.82	0.89	0.96	1.02
0.4	0.77	0.96	1.13	1.30	1.46	1.61	1.76	1.91	2.05	2.19
0.6	1.21	1.50	1.77	2.03	2.28	2.52	2.75	2.98	3.20	3.41
0.8	1.65	2.06	2.43	2.78	3.12	3.45	3.77	4.08	4.38	4.68
1.0	2.11	2.62	3.10	3.55	3.99	4.41	4.81	5.21	5.60	5.98
1.2	2.58	3.20	3.78	4.34	4.87	5.38	5.88	6.37	6.84	7.30
1.4	3.06	3.79	4.48	5.14	5.77	6.38	6.97	7.54	8.10	8.64
1.6	3.53	4.39	5.19	5.95	6.68	7.38	8.07	8.73	9.38	10.01
<i>Large-frame bull calves and compensating large-frame yearling steers</i>										
0.2	0.32	0.40	0.47	0.54	0.60	0.67	0.73	0.79	0.85	0.91
0.4	0.69	0.85	1.01	1.15	1.29	1.43	1.56	1.69	1.82	1.94
0.6	1.07	1.33	1.57	1.80	2.02	2.23	2.44	2.64	2.83	3.02
0.8	1.47	1.82	2.15	2.47	2.77	3.06	3.34	3.62	3.88	4.15
1.0	1.87	2.32	2.75	3.15	3.54	3.91	4.27	4.62	4.96	5.30
1.2	2.29	2.84	3.36	3.85	4.32	4.77	5.21	5.64	6.06	6.47
1.4	2.71	3.36	3.97	4.56	5.11	5.65	6.18	6.68	7.18	7.66
1.6	3.14	3.89	4.60	5.28	5.92	6.55	7.15	7.74	8.31	8.87
1.8	3.56	4.43	5.23	6.00	6.74	7.45	8.13	8.80	9.46	10.10
<i>Medium-frame heifer calves</i>										
0.2	0.49	0.60	0.71	0.82	0.92	1.01	1.11	1.20	1.29	
0.4	1.05	1.31	1.55	1.77	1.99	2.20	2.40	2.60	2.79	
0.6	1.66	2.06	2.44	2.79	3.13	3.46	3.78	4.10	4.40	
0.8	2.29	2.84	3.36	3.85	4.32	4.78	5.22	5.65	6.07	
1.0	2.94	3.65	4.31	4.94	5.55	6.14	6.70	7.25	7.79	
<i>Large-frame heifer calves and compensating medium-frame yearling heifers</i>										
0.2	0.43	0.53	0.63	0.72	0.81	0.90	0.98	1.06	1.14	1.21
0.4	0.93	1.16	1.37	1.57	1.76	1.95	2.13	2.31	2.47	2.64
0.6	1.47	1.83	2.16	2.47	2.78	3.07	3.35	3.63	3.90	4.16
0.8	2.03	2.62	2.98	3.41	3.83	4.24	4.63	5.01	5.38	5.74
1.0	2.61	3.23	3.82	4.38	4.92	5.44	5.94	6.43	6.91	7.37
1.2	3.19	3.97	4.69	5.37	5.03	6.67	7.28	7.88	8.47	9.03

^aShrunk liveweight basis, see text.

TABLE 2 Protein Requirements of Growing and Finishing Cattle (g/day)^a

Body weight, kg:	150	200	250	300	350	400	450	500	550	600
<i>Medium-frame steer calves</i>										
Daily gain, kg										
0.2	343	399	450	499	545	590	633	675	715	
0.4	428	482	532	580	625	668	710	751	790	
0.6	503	554	601	646	688	728	767	805	842	
0.8	575	621	664	704	743	780	815	849	883	
1.0	642	682	720	755	789	821	852	882	911	
1.2	702	735	766	794	822	848	873	897	921	
<i>Large-frame steer calves and compensating medium-frame yearling steers</i>										
0.2	361	421	476	529	579	627	673	719	762	805
0.4	441	499	552	603	651	697	742	785	827	867
0.6	522	576	628	676	722	766	809	850	890	930
0.8	598	650	698	743	786	828	867	906	944	980
1.0	671	718	762	804	843	881	918	953	988	1021
1.2	740	782	822	859	895	929	961	993	1023	1053
1.4	806	842	877	908	938	967	995	1022	1048	1073
1.6	863	892	919	943	967	989	1011	1031	1052	1071
<i>Medium-frame bulls</i>										
0.2	345	401	454	503	550	595	638	680	721	761
0.4	430	485	536	584	629	673	716	757	797	835
0.6	509	561	609	655	698	740	780	819	856	893
0.8	583	632	677	719	759	798	835	871	906	940
1.0	655	698	739	777	813	849	881	914	945	976
1.2	722	760	795	828	860	890	919	947	974	1001
1.4	782	813	841	868	893	917	941	963	985	1006
<i>Large-frame bull calves and compensating large-frame yearling steers</i>										
0.2	355	414	468	519	568	615	661	705	747	789
0.4	438	494	547	597	644	689	733	776	817	857
0.6	519	574	624	672	718	761	803	844	884	923
0.8	597	649	697	741	785	826	866	905	942	979
1.0	673	721	765	807	847	885	922	958	994	1027
1.2	745	789	830	868	904	939	973	1005	1037	1067
1.4	815	854	890	924	956	986	1016	1045	1072	1099
1.6	880	912	943	971	998	1024	1048	1072	1095	1117
1.8	922	942	962	980	997	1013	1028	1043	1057	1071
<i>Medium-frame heifer calves</i>										
0.2	323	374	421	465	508	549	588	626	662	
0.4	409	459	505	549	591	630	669	706	742	
0.6	477	522	563	602	638	674	708	741	773	
0.8	537	574	608	640	670	700	728	755	781	
1.0	582	583	603	621	638	654	670	685	700	
<i>Large-frame heifer calves and compensating medium-frame yearling heifers</i>										
0.2	342	397	449	497	543	588	631	672	712	751
0.4	426	480	530	577	622	665	707	747	787	825
0.6	500	549	596	639	681	721	759	796	832	867
0.8	568	613 ^a	654	693	730	765	799	833	865	896
1.0	630	668	703	735	767	797	826	854	881	907
1.2	680	708	734	758	781	803	824	844	864	883

^aShrunk liveweight basis, see text.

42 Nutrient Requirements of Beef Cattle

TABLE 3 Calcium and Phosphorus Requirements of Growing and Finishing Cattle (g/day)^a

Body Weight, kg	Mineral	150	200	250	300	350	400	450	500	550	600
<i>Medium-frame steer calves</i>											
Daily gain, kg											
0.2	Ca	11	12	13	14	15	16	17	19	20	
	P	7	9	10	12	13	15	16	18	19	
0.4	Ca	16	17	17	18	19	19	20	21	22	
	P	9	10	12	13	14	16	17	18	20	
0.6	Ca	21	21	21	22	22	22	22	23	23	
	P	11	12	13	14	15	17	18	19	20	
0.8	Ca	27	26	25	25	25	25	24	24	24	
	P	12	13	14	15	16	17	19	20	21	
1.0	Ca	32	31	29	29	28	27	26	26	25	
	P	14	15	16	16	17	18	19	20	21	
1.2	Ca	37	35	33	32	31	29	28	27	26	
	P	16	16	17	17	18	19	20	21	21	
1.4	Ca	42	39	37	35	33	32	30	29	27	
	P	17	18	18	19	19	20	20	21	22	
<i>Large-frame steer calves, compensating medium-frame yearling steers, and medium-frame bulls</i>											
0.2	Ca	11	12	13	14	16	17	18	19	20	22
	P	7	9	10	12	13	15	16	18	20	21
0.4	Ca	17	17	18	19	19	20	21	22	23	24
	P	9	10	12	13	15	16	17	19	20	22
0.6	Ca	22	22	23	23	23	24	24	24	25	25
	P	11	12	13	15	16	17	18	20	21	22
0.8	Ca	28	27	27	27	27	27	27	27	27	27
	P	13	14	15	16	17	18	19	20	22	23
1.0	Ca	33	32	31	31	30	30	29	29	29	28
	P	14	15	16	17	18	19	20	21	22	23
1.2	Ca	38	37	36	35	34	33	32	31	30	30
	P	16	17	18	18	19	20	21	22	23	24
1.4	Ca	44	42	40	38	37	36	34	33	32	31
	P	18	18	19	20	20	21	22	22	23	24
1.6	Ca	49	47	44	42	40	38	37	35	34	32
	P	20	20	20	21	21	22	22	23	24	24
<i>Large-frame bull calves and compensating large-frame yearling steers</i>											
0.2	Ca	11	12	13	15	16	17	18	20	21	22
	P	7	9	10	12	13	15	17	18	20	21
0.4	Ca	17	18	19	19	20	21	22	23	24	25
	P	9	11	12	13	15	16	18	19	21	22
0.6	Ca	23	23	23	24	24	25	25	26	27	27
	P	11	12	14	15	16	18	19	20	22	23
0.8	Ca	28	28	28	28	28	29	29	29	29	30
	P	13	14	15	16	18	19	20	21	22	24
1.0	Ca	34	34	33	33	32	32	32	32	32	32
	P	15	16	17	18	19	20	21	22	23	24
1.2	Ca	40	39	38	37	36	36	35	35	34	34
	P	17	17	18	19	20	21	22	23	24	25
1.4	Ca	45	44	42	41	40	39	38	37	36	36
	P	18	19	20	20	21	22	23	24	25	26
1.6	Ca	51	49	47	45	44	42	41	40	39	38
	P	20	21	21	22	23	23	24	25	25	26
1.8	Ca	56	54	51	49	47	45	44	42	41	39
	P	22	22	22	23	23	24	25	25	26	26

TABLE 3 Calcium and Phosphorus Requirements of Growing and Finishing Cattle (g/day)^a—Continued

Body Weight, kg	Mineral	150	200	250	300	350	400	450	500	550	600
<i>Medium-frame heifer calves</i>											
0.2	Ca	10	11	12	13	14	16	17	18	19	
	P	7	9	10	11	13	14	16	17	19	
0.4	Ca	15	16	16	16	17	17	18	19	19	
	P	9	10	11	12	14	15	16	18	19	
0.6	Ca	20	20	19	19	19	19	19	19	19	
	P	10	11	12	13	14	16	17	18	19	
0.8	Ca	25	23	23	22	21	20	20	19	19	
	P	12	12	13	14	15	16	17	18	19	
1.0	Ca	29	27	26	24	23	22	20	19	19	
	P	13	14	14	15	16	16	17	18	19	
<i>Large-frame heifer calves and compensating medium-frame yearling heifers</i>											
0.2	Ca	11	12	13	14	15	16	17	18	20	21
	P	7	9	10	12	13	15	16	18	19	21
0.4	Ca	16	16	17	17	18	19	19	20	21	22
	P	9	10	11	13	14	15	17	18	20	21
0.6	Ca	21	21	21	21	21	21	21	21	22	22
	P	10	12	13	14	15	16	17	19	20	21
0.8	Ca	26	25	24	24	23	23	23	22	22	22
	P	12	13	14	15	16	17	18	19	20	21
1.0	Ca	31	29	28	27	26	25	24	23	23	22
	P	14	14	15	16	17	18	18	19	20	21
1.2	Ca	35	33	31	30	28	27	25	24	23	22
	P	15	16	16	17	17	18	19	20	20	21

^aShrunk liveweight basis, see text.

TABLE 4 Mineral Requirements and Maximum Tolerable Levels for Beef Cattle

Mineral	Requirement		Maximum Tolerable Level ^b
	Suggested Value	Range ^a	
Calcium, %	—	See Tables 3 and 7.	2
Cobalt, ppm	0.10	0.07 to 0.11	5
Copper, ppm	8	4 to 10	115
Iodine, ppm	0.5	0.20 to 2.0	50
Iron, ppm	50	50 to 100	1000
Magnesium, %	0.10	0.05 to 0.25	0.40
Manganese, ppm	40	20 to 50	1000
Molybdenum, ppm	—	—	6
Phosphorus, %	—	See Tables 3 and 7.	1
Potassium, %	0.65	0.5 to 0.7	3
Selenium, ppm	0.20	0.05 to 0.30	2
Sodium, %	0.08	0.06 to 0.10	10 ^c
Chlorine, %	—	—	—
Sulfur, %	0.10	0.08 to 0.15	0.40
Zinc, ppm	30	20 to 40	500

^aThe listing of a range in which requirements are likely to be met recognizes that requirements for most minerals are affected by a variety of dietary and animal (body weight, sex, rate of gain) factors. Thus, it may be better to evaluate rations based on a range of mineral requirements and for content of interfering substances than to meet a specific dietary value.

^bFrom NRC (1980).^c10% sodium chloride.TABLE 5 Maximum Tolerable Levels of Certain Toxic Elements^a

Element	Maximum Tolerable Level, ppm
Aluminum	1,000
Arsenic	50 (100 for organic forms)
Bromine	200
Cadmium	00.5
Fluorine	20 to 100
Lead	30
Mercury	2
Strontium	2,000

^aNRC (1980). Table 4, Mineral Requirements and Maximum Tolerable Levels for Beef Cattle.

44 Nutrient Requirements of Beef Cattle

TABLE 6 Approximate Total Daily Water Intake of Beef Cattle^a

Weight		Temperature in °F (°C) ^b											
		40 (4.4)		50 (10.0)		60 (14.4)		70 (21.1)		80 (26.6)		90 (32.2)	
kg	lb	liter	gal	liter	gal	liter	gal	liter	gal	liter	gal	liter	gal
<i>Growing heifers, steers, and bulls</i>													
182	400	15.1	4.0	16.3	4.3	18.9	5.0	22.0	5.8	25.4	6.7	36.0	9.5
273	600	20.1	5.3	22.0	5.8	25.0	6.6	29.5	7.8	33.7	8.9	48.1	12.7
364	800	23.8	6.3	25.7	6.8	29.9	7.9	34.8	9.2	40.1	10.6	56.8	15.0
<i>Finishing cattle</i>													
273	600	22.7	6.0	24.6	6.5	28.0	7.4	32.9	8.7	37.9	10.0	54.1	14.3
364	800	27.6	7.3	29.9	7.9	34.4	9.1	40.5	10.7	46.6	12.3	65.9	17.4
454	1000	32.9	8.7	35.6	9.4	40.9	10.8	47.7	12.6	54.9	14.5	78.0	20.6
<i>Wintering pregnant cows^c</i>													
409	900	25.4	6.7	27.3	7.2	31.4	8.3	36.7	9.7	—	—	—	—
500	1100	22.7	6.0	24.6	6.5	28.0	7.4	32.9	8.7	—	—	—	—
<i>Lactating cows</i>													
409 +	900 +	43.1	11.4	47.7	12.6	54.9	14.5	64.0	16.9	67.8	17.9	61.3	16.2
<i>Mature bulls</i>													
636	1400	30.3	8.0	32.6	8.6	37.5	9.9	44.3	11.7	50.7	13.4	71.9	19.0
727 +	1600 +	32.9	8.7	35.6	9.4	40.9	10.8	47.7	12.6	54.9	14.5	78.0	20.6

^aWinchester and Morris (1956).

^bWater intake of a given class of cattle in a specific management regime is a function of dry matter intake and ambient temperature. Water intake is quite constant up to 40°F (4.4°C).

^cDry matter intake has a major influence on water intake. Heavier cows are assumed to be higher in body condition and to require less dry matter and, thus, less water intake.

TABLE 7 Nutrient Requirements of Breeding Cattle (metric)

Weight ^a (kg)	Energy				In Diet DM				Total Protein		Calcium		Phosphorus		Vitamin A ^d		
	Daily				In Diet DM				Total Protein		Calcium		Phosphorus		Vitamin A ^d		
	Daily Gain ^b (kg)	DM ^c (kg)	ME (Mcal)	NE _m (Mcal)	NE _g (Mcal)	ME (Mcal/kg)	TDN (%)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	Daily DM (g)	In Diet DM (%)	Daily DM (g)	In Diet DM (%)	Daily DM (g)	In Diet DM (%)	Daily DM (1000's IU)	
Frequent yearling heifers—Last third of pregnancy																	
325	0.4	7.1	14.2	3.9	8.04	NA ^e	2.00	55.2	1.15	NA ^e	591	8.4	19	0.27	14	0.20	20
325	0.6	7.3	15.7	4.3	8.04	0.77	2.15	59.3	1.29	0.72	649	8.9	23	0.32	15	0.21	20
325	0.8	7.5	17.2	4.8	8.04	1.67	2.35	64.9	1.47	0.88	697	9.5	27	0.37	16	0.22	20
350	0.4	7.5	14.8	4.1	8.38	NA	1.99	55.0	1.14	NA	616	8.3	20	0.27	15	0.21	21
350	0.6	7.7	16.5	4.6	8.38	0.81	2.14	59.1	1.28	0.71	674	8.8	24	0.32	16	0.21	22
350	0.8	7.8	18.1	5.0	8.38	1.76	2.34	64.6	1.46	0.88	720	9.2	27	0.35	17	0.22	22
375	0.4	7.6	15.5	4.3	8.71	NA	1.98	54.7	1.13	NA	641	8.2	21	0.27	15	0.19	22
375	0.6	8.1	17.2	4.8	8.71	0.86	2.13	58.8	1.27	0.70	697	8.6	25	0.31	17	0.21	23
375	0.8	8.2	19.0	5.2	8.71	1.86	2.32	64.1	1.45	0.86	743	9.1	27	0.33	18	0.22	23
400	0.4	8.2	16.1	4.5	9.04	NA	1.97	54.4	1.12	NA	664	8.1	22	0.27	16	0.20	23
400	0.6	8.5	18.0	5.0	9.04	0.90	2.12	58.6	1.26	0.69	721	8.5	25	0.30	18	0.20	24
400	0.8	8.6	19.8	5.5	9.04	1.95	2.31	63.8	1.44	0.85	764	8.9	28	0.33	18	0.20	24
425	0.4	8.6	16.8	4.6	9.36	NA	1.96	54.1	1.11	NA	687	8.0	23	0.27	17	0.20	24
425	0.6	8.9	18.7	5.2	9.36	0.94	2.11	58.3	1.25	0.69	743	8.4	26	0.30	18	0.20	25
425	0.8	9.0	20.7	5.7	9.36	2.04	2.30	63.5	1.43	0.84	786	8.8	28	0.31	19	0.21	25
450	0.4	8.9	17.3	4.8	9.67	NA	1.95	53.9	1.10	NA	710	8.0	23	0.26	18	0.20	25
450	0.6	9.2	19.4	5.4	9.67	0.96	2.10	58.0	1.25	0.68	765	8.3	26	0.29	19	0.21	26
450	0.8	9.4	21.5	5.9	9.67	2.13	2.29	63.3	1.42	0.84	807	8.6	28	0.30	20	0.21	26
Dry pregnant mature cows—Middle third of pregnancy																	
350	0.0	6.8	11.9	3.3	6.23	NA	1.76	48.6	0.92	NA	478	7.1	12	0.16	12	0.18	19
400	0.0	7.5	13.1	3.6	6.89	NA	1.76	48.6	0.92	NA	525	7.0	13	0.17	13	0.17	21
450	0.0	8.2	14.3	4.0	7.52	NA	1.76	48.6	0.92	NA	570	7.0	15	0.17	15	0.18	23
500	0.0	8.8	15.5	4.3	8.14	NA	1.76	48.6	0.92	NA	614	7.0	17	0.19	17	0.19	25
550	0.0	9.5	16.7	4.6	8.75	NA	1.76	48.6	0.92	NA	657	6.9	18	0.19	18	0.19	27
600	0.0	10.1	17.8	4.9	9.33	NA	1.76	48.6	0.92	NA	698	6.9	20	0.20	20	0.20	28
650	0.0	10.7	18.9	5.2	9.91	NA	1.76	48.6	0.92	NA	739	6.9	22	0.21	22	0.21	30
Dry pregnant mature cows—Last third of pregnancy																	
350	0.4	7.4	14.7	4.1	8.38	NA	1.98	54.7	1.13	NA	609	8.2	20	0.27	15	0.20	21
400	0.4	8.2	16.0	4.4	9.04	NA	1.96	54.1	1.11	NA	657	8.0	22	0.27	16	0.20	23
450	0.4	8.9	17.2	4.8	9.67	NA	1.94	53.6	1.10	NA	703	7.9	23	0.26	18	0.21	24
500	0.4	9.5	18.3	5.1	10.29	NA	1.92	53.1	1.08	NA	746	7.8	25	0.26	20	0.21	27
550	0.4	10.2	19.5	5.4	10.90	NA	1.91	52.8	1.07	NA	790	7.8	26	0.25	21	0.21	29
600	0.4	10.8	20.6	5.7	11.48	NA	1.90	52.5	1.06	NA	832	7.7	28	0.26	23	0.21	30
650	0.4	11.5	21.7	6.0	12.06	NA	1.89	52.2	1.05	NA	872	7.6	30	0.26	25	0.22	32
Two-year-old heifers nursing calves—First 3–4 months postpartum—5.0 kg milk/day																	
300	0.2	6.9	16.6	4.6	9.30 ^f	0.72	2.41	66.6	1.53	0.93	814 ^g	11.8	26	0.38	17	0.25	27
325	0.2	7.3	17.4	4.8	9.64 ^f	0.77	2.37	65.5	1.49	0.90	841 ^g	11.5	27	0.37	18	0.25	28
350	0.2	7.8	18.1	5.0	9.98 ^f	0.81	2.34	64.6	1.46	0.88	866 ^g	11.2	27	0.35	19	0.24	30
375	0.2	8.2	18.9	5.2	10.31 ^f	0.86	2.31	63.8	1.44	0.85	892 ^g	10.9	28	0.34	19	0.23	32
400	0.2	8.6	19.7	5.4	10.64 ^f	0.90	2.29	63.3	1.42	0.84	916 ^g	10.7	28	0.33	20	0.23	34
425	0.2	9.0	20.4	5.6	10.96 ^f	0.94	2.27	62.7	1.40	0.82	939 ^g	10.5	29	0.32	21	0.23	35
450	0.2	9.4	21.1	5.8	11.27 ^f	0.98	2.25	62.2	1.38	0.80	963 ^g	10.3	29	0.31	22	0.23	37

TABLE 7 Nutrient Requirements of Breeding Cattle (metric)—Continued

Weight ^a (kg)	Energy										Phosphorus				Vitamin A ^d	
	Daily										Calcium		In Diet		Daily	
	Daily Gain ^b (kg)	ME (Mcal)	TDN (kg)	NE _m (Mcal)	NE _g (Mcal)	ME (Mcal/kg)	TDN (%)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	Daily (g)	In Diet (%)	Daily (g)	In Diet (%)	Daily (1000's IU)		
<i>Cows nursing calves—Average milking ability—First 3–4 months postpartum—5.0 kg milk/day</i>																
350	0.0	7.7	16.6	4.6	9.98 ^f	NA	2.15	59.4	1.29	814 ^g	10.6	23	0.30	18	0.23	
400	0.0	8.5	17.9	4.9	10.64 ^f	NA	2.11	58.3	1.25	864 ^g	10.2	25	0.29	19	0.22	
450	0.0	9.2	19.1	5.3	11.27 ^f	NA	2.08	57.5	1.23	911 ^g	9.9	26	0.28	21	0.23	
500	0.0	9.9	20.3	5.6	11.89 ^f	NA	2.05	56.6	1.20	957 ^g	9.7	28	0.28	22	0.22	
550	0.0	10.6	21.5	5.9	12.50 ^f	NA	2.03	56.1	1.18	1001 ^g	9.5	29	0.27	24	0.23	
600	0.0	11.2	22.6	6.2	13.08 ^f	NA	2.01	55.5	1.16	1044 ^g	9.3	31	0.28	26	0.23	
650	0.0	11.9	23.9	6.6	13.66 ^f	NA	2.00	55.3	1.15	1086 ^g	9.1	33	0.28	27	0.23	
<i>Cows nursing calves—Superior milking ability—First 3–4 months postpartum—10.0 kg milk/day</i>																
350	0.0	6.2	18.5	5.1	13.73 ^f	NA	3.00	82.9	2.03	NA		36	0.58	24	0.39	
400	0.0	7.6	21.4	5.9	14.39 ^f	NA	2.80	77.4	1.86	NA		37	0.49	25	0.33	
450	0.0	9.1	23.2	6.4	15.02 ^f	NA	2.56	70.7	1.66	NA		39	0.43	26	0.29	
500	0.0	10.0	24.6	6.8	15.64 ^f	NA	2.45	67.7	1.56	NA		40	0.40	28	0.28	
550	0.0	10.9	25.8	7.1	16.25 ^f	NA	2.38	65.8	1.50	NA		42	0.39	30	0.27	
600	0.0	11.6	27.0	7.5	16.83 ^f	NA	2.32	64.1	1.45	NA		43	0.37	31	0.27	
650	0.0	12.4	28.2	7.8	17.41 ^f	NA	2.28	63.0	1.41	NA		45	0.36	33	0.26	
<i>Bulls, maintenance and regaining body condition</i>																
<i><650 For growth and development use requirements for bulls in Tables 1, 2, and 3.</i>																
650	0.4	12.3	24.3	6.7	9.91	2.06	1.98	54.8	1.13	904	7.4	25	0.20	23	0.19	
700	0.6	12.6	26.7	7.4	9.91	3.21	2.11	58.4	1.25	957	7.6	27	0.21	24	0.19	
750	0.8	12.8	28.7	7.9	9.91	4.40	2.24	62.0	1.37	998	7.8	29	0.23	25	0.20	
800	0.4	13.0	25.7	7.1	10.48	2.18	1.96	54.8	1.13	942	7.3	26	0.20	25	0.20	
850	0.6	13.4	28.2	7.8	10.48	3.40	2.11	58.4	1.25	994	7.4	29	0.22	26	0.20	
900	0.8	13.5	30.3	8.4	10.48	4.66	2.24	62.0	1.37	1032	7.6	30	0.22	26	0.19	
950	0.0	12.9	29.6	8.3	11.58	NA	1.75	48.4	0.91	882	6.8	27	0.21	27	0.21	
1000	0.2	13.7	25.5	7.1	11.58	1.12	1.86	51.5	1.02	956	7.0	27	0.20	27	0.20	
1050	0.0	14.1	24.7	6.8	12.65	NA	1.75	48.4	0.91	958	6.8	30	0.21	30	0.21	
1100	0.2	15.0	27.9	7.7	12.65	1.23	1.86	51.5	1.02	1031	6.9	31	0.21	31	0.21	
1150	0.0	15.3	26.8	7.4	13.69	NA	1.75	48.4	0.91	1032	6.8	33	0.22	33	0.22	

^aAverage weight for a feeding period.^bApproximately 0.4 ± 0.1 kg of weight gain over the last third of pregnancy is accounted for by the products of conception. Daily 2.15 Mcal of NE_m and 55 g of protein are provided for this requirement for a calf with a birth weight of 30 kg.^cDry matter consumption should vary depending on the energy concentration of the diet and environmental conditions. These intakes are based on the energy concentration shown in the table and assuming a thermoneutral environment without snow or mud conditions. If the energy concentrations of the diet to be fed exceed the tabular value, limit feeding may be required.^dVitamin A requirements per kilogram of diet are 2800 IU for pregnant heifers and cows and 3800 IU for lactating cows and breeding bulls.^eNot applicable.^fIncludes 75 Mcal NE_m/kg of milk produced.^gIncludes 33.5 g protein/kg of milk produced.

7 Composition of Feeds and Mineral Supplements

Table 8 gives the composition of feeds commonly used for beef cattle. Some names have been shortened and the listing of feeds is slightly reorganized compared with the previous edition of this report. Mineral supplements are listed in a separate table. International Feed Numbers (IFNs) have been retained. For a complete nomenclature of the feeds appearing in Table 8, the reader is referred to the third revision of *United States-Canadian Tables of Feed Composition* (NRC, 1982), which also contains a table of weight-unit conversion factors.

The energy values in Table 8 were calculated as follows (Garrett, 1980):

$$ME = 0.82 DE.$$

$$NE_m = 1.37 ME - 0.138 ME^2 + 0.0105 ME^3 - 1.12.$$

$$NE_g = 1.42 ME - 0.174 ME^2 + 0.0122 ME^3 - 1.65.$$

Additional feeds may be found in the third revision of *United States-Canadian Tables of Feed Composition*. If those feeds are to be used with prediction equations in this report, the ME and NE values need to be recalculated using the above equations. For some feedstuffs, energy values are not available from digestibility trials.

Digestibility energy values may be estimated from the following formula:

$$\begin{aligned} DE \text{ (Mcal/kg)} = & 0.0504 \text{ CP\%} + 0.0770 \text{ EE\%} \\ & + 0.0200 \text{ CF\%} + 0.000377 \text{ NFE}^2\% \\ & + 0.0110 \text{ NFE\%} - 0.152. \end{aligned}$$

This formula and a listing of unusual and by-product feeds for cattle are included in Western Regional Extension Publication Number 39, Cooperative Extension Service, University of California, Berkeley, 94720.

It should be realized that the values given in Table 8 are the best estimate of the composition of that particular feed for beef cattle. Many factors affect the composition of feeds, such as soil conditions and climate, and these should be taken into consideration.

Where data are available, plant cell constituents are given, because of the increasing use of these values in dietary formulations. When available, values are also given for crude fiber.

Table 9 lists the minerals commonly used in dietary formulations for beef cattle. Both the feed composition and mineral tables are expressed on a dry matter basis.

The vitamin A activity shown in Table 8 is based on the equivalence of 1 mg of β -carotene to 400 IU of vitamin A.

48 Nutrient Requirements of Beef Cattle

TABLE 8 Composition of Some Beef Cattle Feeds

Entry Number	Feed Name Description	International Feed Number*	Dry Basis (100% Dry Matter)										Crude Fiber (%)	Cell Walls (%)
			Dry Matter (%)	DE (Mcal/kg)	ME (Mcal/kg)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	TDN (%)	Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)		
001	ALFALFA <i>Medicago sativa</i>	2-00-181	21	2.78	2.28	1.41	0.83	63	20.0	2.7	9.8	23.0	38	
002	fresh, late vegetative	2-00-184	23	2.65	2.17	1.31	0.74	60	19.0	3.1	9.5	25.0	40	
003	fresh, early bloom	2-00-185	24	2.56	2.10	1.24	0.68	58	18.3	2.6	8.7	28.0	46	
004	fresh, full bloom	2-00-188	25	2.43	1.99	1.14	0.58	55	14.0	2.8	8.5	31.0	52	
005	hay, sun-cured, early bloom	1-00-059	90	2.65	2.17	1.31	0.74	60	18.0	3.0	9.6	23.0	42	
006	hay, sun-cured, midbloom	1-00-063	90	2.56	2.10	1.24	0.68	58	17.0	2.6	9.1	26.0	46	
007	hay, sun-cured, late bloom	1-20-681	90	2.29	1.88	1.04	0.49	52	14.0	1.8	7.8	32.0	52	
008	hay, sun-cured, mature	1-00-071	91	2.21	1.81	0.97	0.42	50	12.9	1.3	7.5	37.7	58	
009	meal dehydrated, 17% protein	1-00-023	92	2.69	2.21	1.34	0.77	61	18.9	3.0	10.6	26.2	45	
010	silage wilted, early bloom	3-00-216	35	2.65	2.17	1.31	0.74	60	17.0	3.2	8.2	28.0	43	
011	silage wilted, midbloom	3-00-217	38	2.56	2.10	1.24	0.68	58	15.5	3.1	7.9	30.0	47	
012	silage wilted, full bloom	3-00-218	45	2.43	1.99	1.14	0.58	55	14.0	2.7	7.7	33.2	51	
013	ALMOND <i>Prunus amygdalus</i> hulls	4-00-359	90	2.43	1.99	1.14	0.58	55	2.1	3.0	6.5	15.0	32	
014	APPLE <i>Malus</i> spp. pomace oat hulls added, dehydrated	4-28-096	89	2.47	2.03	1.18	0.61	56	5.1	5.2	3.5	30.0	—	
015	BAHAGRASS <i>Paspalum notatum</i>	2-00-464	30	2.38	1.95	1.11	0.55	54	8.9	1.6	11.1	30.4	68	
016	hay, sun-cured	1-00-462	91	2.25	1.84	1.00	0.45	51	8.2	2.1	6.4	32.0	72	
017	BAKERY waste, dehydrated (dried bakery product)	4-00-466	92	3.92	3.22	2.21	1.52	89	10.7	12.7	4.4	1.3	—	
018	BARLEY <i>Hordeum vulgare</i> grain	4-00-548	88	3.70	3.04	2.06	1.40	84	13.5	2.1	2.6	5.7	19	
019	grain, Pacific coast	4-07-939	89	3.79	3.11	2.12	1.45	86	10.8	2.0	3.1	7.1	21	
020	grain screenings	4-00-542	89	3.53	2.89	1.94	1.30	80	13.1	2.6	3.4	9.6	—	
021	hay, sun-cured	1-00-495	87	2.47	2.03	1.18	0.61	56	8.7	2.1	7.6	27.5	—	
022	silage	3-00-512	31	2.25	1.84	1.00	0.45	51	10.3	3.9	10.2	30.0	—	
023	straw	1-00-498	91	1.76	1.45	0.60	0.08	40	4.3	1.9	7.1	42.0	80	
024	BEAN, NAVY <i>Phaseolus vulgaris</i> seed	5-00-623	89	3.70	3.04	2.06	1.40	84	25.3	1.5	5.2	5.0	—	
025	BET, MANGEL <i>Beta vulgaris</i> macrorrhiza roots, fresh	4-00-637	11	3.53	2.89	1.94	1.30	80	11.8	0.7	9.6	7.4	—	
026	BET, SUGAR <i>Beta vulgaris altissima</i> aerial part with crowns, silage	3-00-660	22	2.25	1.84	1.00	0.45	51	13.4	2.8	32.5	13.7	—	
027	BERMUDAGRASS <i>Cynodon dactylon</i> pulp, dehydrated	4-00-660	91	3.26	2.68	1.76	1.14	74	9.7	0.6	5.4	19.8	54	
028	pulp, wet	4-00-671	11	3.17	2.60	1.70	1.08	72	11.2	2.1	4.7	28.1	—	
029	pulp with molasses, dehydrated	4-00-672	92	3.35	2.75	1.82	1.19	76	10.1	0.6	6.1	16.5	44	
030	BERMUDAGRASS <i>Cynodon dactylon</i> fresh	2-00-712	34	2.65	2.17	1.31	0.74	60	12.0	2.2	10.2	36.4	—	
031	hay, sun-cured	1-00-703	91	2.03	1.66	0.83	0.29	46	9.8	2.0	9.2	30.4	—	
032	BERMUDAGRASS, COASTAL <i>Cynodon dactylon</i> fresh	2-00-719	29	2.82	2.31	1.44	0.86	64	15.0	3.8	6.3	28.4	—	
033	hay, sun-cured	1-00-716	90	2.16	1.77	0.93	0.39	40	6.0	2.3	6.6	30.7	78	
034	BLUEGRASS, CANADA <i>Poa compressa</i> fresh, early vegetative	2-00-763	26	3.13	2.57	1.67	1.06	71	18.7	3.7	9.1	25.5	—	
035	hay, sun-cured, late vegetative	1-20-889	97	2.12	1.74	0.90	0.35	48	—	—	—	—	—	
036	BLUEGRASS, KENTUCKY <i>Poa pratensis</i> fresh, early vegetative	2-00-777	31	3.17	2.60	1.70	1.06	72	17.4	3.6	9.4	25.3	55	
037	fresh, mature	2-00-784	42	2.47	2.03	1.18	0.61	56	9.5	3.1	6.2	32.2	69	
038	hay, sun-cured	1-00-776	89	2.47	2.03	1.18	0.61	56	13.0	3.5	6.6	31.0	—	
039	hay, sun-cured, full bloom	1-00-772	92	2.12	1.74	0.90	0.35	48	8.9	3.3	5.9	32.5	—	
040	BLUESTEM <i>Andropogon</i> spp. fresh, early vegetative	2-00-821	27	3.00	2.46	1.57	0.97	68	12.8	2.8	8.9	34.9	—	
041	fresh, mature	2-00-825	59	2.34	1.92	1.07	0.52	53	5.8	2.4	5.6	34.2	—	
042	BREWERS grains, dehydrated	5-02-141	92	2.91	2.39	1.51	0.91	66	29.4	7.2	3.9	14.4	46	
043	grains, wet	5-02-142	21	2.91	2.39	1.51	0.91	66	23.2	6.5	4.8	15.3	42	
044	BROME <i>Bromus</i> spp. fresh, early vegetative	2-00-892	34	2.26	2.68	1.76	1.14	74	18.0	3.7	10.7	24.0	58	
045	hay, sun-cured, late vegetative	1-00-887	88	2.65	2.17	1.31	0.74	60	16.0	2.6	9.4	30.0	65	
046	hay, sun-cured, late bloom	1-00-888	89	2.43	1.99	1.14	0.58	55	10.0	2.3	8.4	37.0	88	
047	BROME, SMOOTH <i>Bromus inermis</i> fresh, early vegetative	2-00-956	30	3.22	2.64	1.73	1.11	73	21.3	4.2	10.1	22.8	49	
048	fresh, mature	2-06-364	55	2.34	1.92	1.07	0.52	53	6.0	2.4	6.9	34.8	—	
049	hay, sun-cured, midbloom	1-05-633	90	2.47	2.03	1.18	0.61	56	14.6	2.6	10.0	31.8	61	

Entry Number	Acid Detergent Fiber (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Carotene (Provitamin A) Activity (1000 IU/kg)
001	29	7	22	7	2.19	0.44	0.27	0.33	2.14	0.21	0.48	0.17	11	—	111	41	—	—	—
002	31	8	23	7	2.33	—	—	0.31	1.92	—	—	—	—	—	—	—	—	—	69.8
003	35	10	26	9	2.01	0.45	0.26	0.28	2.06	0.16	0.29	—	—	—	—	—	—	—	56.7
004	37	13	27	10	1.53	0.43	0.27	0.27	2.13	0.15	0.31	—	—	—	430	155	—	—	—
005	31	9	24	8	1.41	0.38	0.33	0.22	2.52	0.14	0.28	0.16	11	—	192	31	0.54	25	56.1
006	35	10	26	9	1.41	0.38	0.31	0.24	1.71	0.12	0.28	0.36	14	—	134	28	—	23	13.3
007	39	12	26	12	1.43	—	0.14	0.25	2.45	—	—	—	—	14	—	170	43	—	31
008	44	13	29	14	1.13	—	0.27	0.18	1.78	0.08	0.25	0.09	14	—	153	44	—	24	4.6
009	35	—	24	11	1.52	0.52	0.32	0.25	2.60	0.11	0.24	0.33	11	0.16	441	34	0.37	21	52.4
010	33	9	23	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
011	35	10	24	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
012	38	12	25	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
013	26	—	—	9	0.23	—	—	0.11	0.53	—	0.11	—	—	—	—	—	—	—	—
014	45	—	—	14	0.13	—	0.07	0.12	0.49	0.14	0.02	—	—	—	299	8	—	—	—
015	36	—	—	7	0.46	—	0.25	0.22	1.45	—	—	—	—	—	—	—	—	—	73.0
016	41	30	32	8	0.50	—	0.19	0.22	—	—	—	—	—	—	60	—	—	—	—
017	2	—	—	—	0.14	1.61	0.26	0.26	0.53	1.24	0.02	1.05	5	—	31	71	—	16	1.9
018	7	—	5	2	0.05	0.18	0.15	0.38	0.47	0.03	0.17	0.10	9	0.05	85	18	0.22	19	0.9
019	9	—	—	—	0.06	0.17	0.14	0.39	0.58	0.02	0.16	0.10	9	—	97	18	0.11	17	—
020	—	—	—	—	0.34	—	0.14	0.33	0.75	0.02	0.15	—	—	—	60	—	—	—	—
021	—	—	—	—	0.23	—	0.18	0.26	1.18	0.14	0.17	0.07	34	—	101	27	0.16	48	21.0
022	—	—	—	—	0.34	—	0.13	0.28	2.01	0.01	0.11	0.67	5	—	274	79	0.09	22	10.2
023	49	44	37	11	0.30	0.67	0.23	0.07	2.37	0.14	0.17	0.07	5	—	201	17	—	7	0.9
024	—	—	—	—	0.18	0.06	0.15	0.59	1.47	0.05	0.26	—	11	—	110	24	—	—	—
025	—	—	—	—	0.18	1.41	0.20	0.22	2.30	0.63	0.20	—	6	—	154	—	—	—	0.4
026	—	—	—	—	1.56	—	1.07	0.29	5.74	0.54	0.57	—	—	—	300	—	—	—	—
027	33	—	—	2	0.60	0.04	0.27	0.10	0.20	0.21	0.22	0.08	14	—	329	38	—	1	0.1
028	—	—	—	—	0.87	—	0.22	0.10	0.19	0.19	0.22	—	—	—	330	—	—	1	—
029	25	—	—	3	0.61	—	0.16	0.10	1.78	0.53	0.42	0.23	16	—	207	27	—	2	0.1
030	—	—	—	—	0.53	—	0.17	0.21	1.70	—	—	0.08	6	—	—	—	—	—	124.1
031	—	—	—	—	0.47	—	0.17	0.17	1.53	0.08	0.21	0.12	—	0.12	290	—	—	—	23
032	—	—	—	—	0.49	—	—	0.27	—	—	—	—	—	—	—	—	—	—	132.2
033	38	—	—	6	0.43	—	0.17	0.20	1.61	0.44	0.21	—	—	—	300	—	—	11	41.8
034	—	—	—	—	0.39	—	0.16	0.39	2.04	0.14	0.17	—	—	—	300	—	—	—	160
035	—	—	—	—	0.30	—	0.33	0.29	1.59	0.11	0.13	—	—	—	—	—	—	—	135.0
036	29	—	26	3	0.50	—	0.18	0.44	2.27	0.14	0.17	—	—	—	300	—	—	—	192.8
037	40	21	34	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	36.7
038	—	—	—	—	0.33	0.53	0.16	0.25	1.69	0.13	0.16	—	10	—	293	70	—	—	—
039	—	—	—	—	0.26	—	—	0.27	1.52	—	—	—	—	—	—	—	—	—	—
040	—	—	—	—	0.63	—	—	0.20	1.72	—	—	—	47	—	895	106	—	—	87.7
041	—	—	—	—	0.40	—	0.06	0.12	0.51	—	—	—	26	—	1075	61	—	—	—
042	24	—	—	6	0.33	0.17	0.16	0.55	0.09	0.23	0.32	0.08	23	0.07	266	40	0.76	30	—
043	23	—	5	3	0.33	0.17	0.16	0.55	0.09	0.23	0.32	0.10	23	0.07	266	40	0.76	30	—
044	31	—	27	3	0.50	—	0.18	0.30	2.30	0.02	0.20	—	—	—	300	—	—	—	183.8
045	35	—	32	4	0.32	—	0.09	0.37	2.32	0.02	0.20	—	—	—	—	—	—	—	26.0
046	43	—	36	8	0.30	—	0.09	0.35	2.32	0.02	0.20	—	—	—	—	—	—	—	15.0
047	27	22	20	4	0.55	—	0.32	0.45	3.16	—	—	—	—	—	—	—	—	—	233.2
048	—	—	—	—	0.26	—	—	0.16	—	—	—	—	2	—	—	—	—	—	—
049	37	22	31	4	0.29	—	0.10	0.28	1.99	0.01	—	0.58	25	—	91	40	—	30	—

TABLE 8 Composition of Some Beef Cattle Feeds—Continued

Entry Number	Feed Name Description	International Feed Number ^a	Dry Matter (%)	Dry Basis (100% Dry Matter)					Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)	Cell Walls (%)
				DE (Mcal/kg)	ME (Mcal/kg)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	TDN (%)					
	BUCKWHEAT, COMMON <i>Fagopyrum sagittatum</i>												
050	grain	4-00-994	88	3.17	2.60	1.70	1.08	72	12.5	2.8	2.3	11.8	—
	BUFFALOGRASS <i>Buchloe dactyloides</i>												
051	fresh	2-01-010	46	2.47	2.03	1.18	0.61	56	10.3	1.9	12.4	26.7	74
	CANARYGRASS, REED <i>Phalaris arundinacea</i>												
052	fresh	2-01-113	27	2.65	2.17	1.31	0.74	60	11.6	3.5	8.3	29.5	46
053	hay, sun-cured	1-01-104	91	2.43	1.99	1.14	0.58	55	10.3	3.1	7.9	33.0	64
	CARROT <i>Daucus</i> spp												
054	roots, fresh	4-01-145	12	3.70	3.04	2.06	1.40	84	9.9	1.4	8.2	9.7	9
	CASSAVA, COMMON <i>Manihot esculenta</i>												
055	tubers, meal	4-09-598	88	3.75	3.07	2.09	1.43	85	2.6	0.8	3.3	5.2	—
056	tubers, fresh	4-09-599	37	3.53	2.89	1.94	1.30	80	3.8	1.0	3.9	4.6	—
	CATTLE <i>Bos taurus</i>												
057	manure, dehydrated, all forage	1-28-274	92	1.10	0.90	0.01	—	25	17.0	—	—	—	69
058	manure, dehydrated (high concentrate)	1-28-213	92	1.90	1.56	0.72	0.18	43	25.0	—	19.8	—	32
059	manure, dehydrated, forage and concentrate	1-28-214	92	1.32	1.09	0.22	—	30	17	2.8	5.4	31.4	58
	CEREALS												
060	grain screenings	4-02-156	90	3.00	2.46	1.57	0.97	68	13.4	4.1	6.0	13.4	—
061	grain screenings refuse	4-02-151	91	2.65	2.17	1.31	0.74	60	14.1	4.9	9.8	18.7	—
062	grain screenings, uncleaned	4-02-153	92	2.87	2.35	1.47	0.88	65	15.1	5.9	9.3	18.6	—
	CITRUS <i>Citrus</i> spp												
063	pulp, silage	4-01-234	21	3.88	3.18	2.18	1.50	88	7.3	9.7	5.5	15.6	—
064	pulp without fines, dehydrated (dried citrus pulp)	4-01-237	91	3.62	2.97	2.00	1.35	82	6.7	3.7	6.6	12.7	23
	CLOVER, ALSIKE <i>Trifolium hybridum</i>												
065	fresh, early vegetative	2-01-314	19	2.91	2.39	1.51	0.91	66	24.1	3.2	12.8	17.5	—
066	hay, sun-cured	1-01-313	88	2.56	2.10	1.24	0.68	58	14.9	3.0	8.7	30.1	—
	CLOVER, CRIMSON <i>Trifolium incarnatum</i>												
067	fresh, early vegetative	2-20-800	18	2.78	2.28	1.41	0.83	63	17.0	—	—	28.0	—
068	hay, sun-cured	1-01-328	87	2.51	2.06	1.21	0.64	57	18.4	2.4	11.0	30.1	—
	CLOVER, LADINO <i>Trifolium repens</i>												
069	fresh, early vegetative	2-01-380	19	3.00	2.46	1.57	0.97	68	27.2	2.5	13.5	14.0	—
070	hay, sun-cured	1-01-378	90	2.65	2.17	1.31	0.74	60	22.0	2.7	10.1	21.2	36
	CLOVER, RED <i>Trifolium pratense</i>												
071	fresh, early bloom	2-01-428	30	3.04	2.50	1.60	1.00	69	19.4	5.0	10.2	23.2	—
072	fresh, full bloom	2-01-429	26	2.82	2.31	1.44	0.86	64	14.8	2.9	7.8	26.1	—
073	fresh, regrowth early vegetative	2-28-255	18	3.00	2.46	1.57	0.97	68	21.0	—	—	—	—
074	hay, sun-cured	1-01-415	89	2.43	1.99	1.14	0.58	55	16.0	2.8	8.5	28.8	56
	COCONUT <i>Cocos nucifera</i>												
075	kernels with coats, meal mechanical extracted (copra meal)	5-01-572	92	3.62	2.97	2.00	1.35	82	22.4	6.9	7.3	12.8	—
076	kernels with coats, meal solvent extracted (copra meal)	5-01-573	91	3.31	2.71	1.79	1.16	75	23.4	3.9	6.6	15.4	—
	CORN, DENT YELLOW <i>Zea mays indentata</i>												
077	aerial part with ears, sun-cured (fodder)	1-28-231	81	2.87	2.35	1.47	0.88	65	8.9	2.4	6.8	25.2	55
078	aerial part with ears, sun-cured, mature (fodder)	1-28-232	82	3.04	2.50	1.60	1.00	69	8.0	2.3	5.4	22.6	—
079	aerial part without ears, without husks, sun-cured (stover) (straw)	1-28-233	85	2.21	1.81	0.97	0.42	50	6.6	1.3	7.2	34.4	67
080	cobs, ground	1-28-234	90	2.21	1.81	0.97	0.42	50	3.2	0.7	1.7	36.2	89
081	distillers grains, dehydrated	5-28-235	94	3.79	3.11	2.12	1.45	86	23.0	9.8	2.4	12.1	43
082	distillers grains with solubles, dehydrated	5-28-236	92	3.88	3.18	2.18	1.50	88	25.0	10.3	4.8	9.9	44
	distillers solubles, dehydrated	5-28-237	93	3.88	3.18	2.18	1.50	88	29.7	9.2	7.8	5.0	23
084	ears, ground (corn and cob meal)	4-28-238	87	3.66	3.00	2.03	1.37	83	9.0	3.7	1.9	9.4	—
085	ears with husks, silage	4-28-239	44	3.26	2.68	1.76	1.14	74	8.9	3.8	2.8	11.6	—
086	gluten, meal	5-28-241	91	3.79	3.11	2.12	1.45	86	46.8	2.4	3.4	4.8	37
087	gluten, meal 60% protein	5-28-242	90	3.92	3.22	2.21	1.52	89	67.2	2.4	1.8	2.2	14
088	gluten with bran (corn gluten feed)	5-28-243	90	3.66	3.00	2.03	1.37	83	25.6	2.4	7.5	9.7	—
089	grain, grade 2, 69.5 kg/hl	4-02-831	88	3.97	3.25	2.24	1.55	90	10.1	4.2	1.4	2.2	—
090	grain, flaked	4-28-244	86	4.19	3.44	2.38	1.67	95	11.2	2.2	1.0	0.7	—
091	grain, high moisture	4-20-770	72	4.10	3.36	2.33	1.62	93	10.7	4.3	1.6	2.6	—
092	grits by-product (hominy feed)	4-03-011	90	4.14	3.40	2.35	1.65	94	11.5	7.7	3.1	6.7	55

Entry Number	Acid Detergent Fiber (%)	Hemi-cellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Carotene (Provitamin A) Activity (1000 IU/kg)
050	—	—	—	—	0.11	0.05	0.12	0.37	0.51	0.06	0.16	0.06	11	—	50	38	—	10	—
051	36	—	—	6	0.57	—	0.14	0.21	0.71	—	—	—	—	—	—	—	—	—	37.5
052	28	20	22	4	0.41	—	—	0.35	3.64	—	—	—	—	—	—	—	—	—	—
053	30	23	26	4	0.38	—	0.29	0.25	2.76	0.14	—	0.02	12	—	150	118	—	—	10.3
054	8	—	7	0	0.40	0.50	0.20	0.35	2.80	1.04	0.17	—	10	—	120	31	—	—	271.0
055	—	—	—	—	0.28	—	—	0.19	0.26	—	—	—	—	—	9	20	—	—	—
056	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
057	46	—	—	27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
058	26	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
059	34	26	30	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
060	—	—	—	—	0.37	—	0.14	0.39	0.34	0.45	—	—	—	—	—	49	—	—	—
061	—	—	—	—	0.32	—	0.24	0.37	0.20	0.28	0.33	—	—	—	270	—	0.72	—	—
062	—	—	—	—	0.40	—	0.23	0.45	0.20	0.28	0.33	—	5	—	270	—	0.87	37	—
063	—	—	—	—	2.04	—	0.16	0.15	0.62	0.09	0.02	—	—	—	160	—	—	16	—
064	22	—	—	3	1.84	—	0.17	0.12	0.70	0.09	0.08	0.16	6	—	378	7	—	15	0.1
065	—	—	—	—	1.19	—	0.34	0.42	2.31	—	—	—	—	—	—	—	—	—	154.0
066	—	13	—	—	1.29	0.78	0.41	0.26	2.46	0.46	0.19	—	6	—	280	69	—	—	74.8
067	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	95.0
068	—	—	—	—	1.40	0.63	0.28	0.22	2.40	0.39	0.28	—	—	0.07	700	171	—	—	9.0
069	—	—	—	—	1.93	—	0.42	0.35	—	0.12	0.16	—	—	—	—	—	—	—	141.0
070	32	—	7	—	1.35	0.30	0.48	0.31	2.62	0.13	0.21	0.16	10	0.30	413	95	—	17	33.4
071	—	—	—	—	2.26	—	0.51	0.38	2.49	0.20	0.17	—	—	—	300	—	—	—	99.0
072	—	—	—	—	1.01	—	0.51	0.27	1.96	0.20	0.17	—	—	—	300	—	—	—	83.0
073	—	—	—	—	1.64	—	0.51	0.36	2.44	0.20	0.17	—	—	—	300	—	—	—	—
074	36	9	26	10	1.53	0.32	0.43	0.25	1.62	0.19	0.17	0.16	11	0.25	184	73	—	17	7.9
075	—	—	—	—	0.22	—	0.33	0.66	1.62	0.04	0.36	0.14	15	—	1651	71	—	53	—
076	—	—	—	—	0.19	0.03	0.36	0.66	1.63	0.04	0.37	0.14	10	—	750	72	—	—	—
077	33	—	28	3	0.50	0.19	0.29	0.25	0.93	0.03	0.14	—	8	—	100	68	—	—	1.8
078	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
079	39	—	25	11	0.57	—	0.40	0.10	1.45	0.07	0.17	—	5	—	210	136	—	—	1.8
080	35	—	28	7	0.12	—	0.07	0.04	0.87	0.47	0.47	0.13	7	—	230	6	—	—	0.3
081	—	—	—	—	0.11	0.08	0.07	0.43	0.18	0.10	0.46	0.09	48	0.05	223	23	0.48	35	1.3
082	18	—	14	4	0.15	0.18	0.18	0.71	0.44	0.57	0.33	0.18	58	—	259	25	0.42	—	1.4
083	7	—	6	1	0.35	0.28	0.65	1.37	1.80	0.25	0.40	0.21	89	0.12	610	80	0.36	92	0.3
084	—	—	—	—	0.07	0.05	0.14	0.27	0.53	0.02	0.16	0.31	8	0.03	91	14	0.09	14	1.5
085	—	—	—	—	0.10	—	0.12	0.29	0.49	0.01	0.13	—	—	—	80	—	—	—	3.1
086	9	—	8	1	0.16	0.07	0.06	0.50	0.03	0.10	0.39	0.08	30	—	423	8	1.11	190	7.1
087	5	—	4	1	0.08	0.10	0.09	0.54	0.21	0.06	0.72	0.05	29	0.02	313	7	0.92	35	13.4
088	—	—	—	—	0.36	0.25	0.36	0.82	0.64	1.05	0.23	0.10	52	0.07	471	26	0.30	72	2.8
089	—	—	—	—	0.02	0.05	0.13	0.35	0.37	0.02	0.14	0.04	4	—	26	6	—	16	0.8
090	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
091	5	—	—	—	0.02	0.05	0.14	0.32	0.35	0.01	0.14	—	4	—	30	6	—	18	—
092	13	17	10	2	0.05	0.06	0.26	0.57	0.65	0.09	0.03	0.06	15	0.07	75	16	0.11	3	4.1

TABLE 8 Composition of Some Beef Cattle Feeds—Continued

Dry Basis (100% Dry Matter)													
Entry Number	Feed Name Description	International Feed Number*	Dry Matter (%)	DE (Mcal/kg)	ME (Mcal/kg)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	TDN (%)	Crude Protein (%)	Fiber Extract (%)	Ash (%)	Crude Fiber (%)	Cell Walls (%)
093	silage, aerial part without ears, without husks (stalkage) (stover)	3-26-251	31	2.43	1.99	1.14	0.58	55	6.3	2.1	11.6	31.3	68
094	silage, few ears	3-26-245	29	2.73	2.24	1.38	0.80	62	8.4	3.0	7.2	32.3	—
095	silage, well eared	3-26-250	33	3.09	2.53	1.63	1.03	70	8.1	3.1	4.5	33.7	51
096	CORN, SWEET <i>Zea mays saccharata</i> process residue, fresh (cannery residue)	2-02-975	77	3.09	2.53	1.63	1.03	70	8.8	2.3	3.3	22.3	—
097	process residue, silage (cannery residue)	3-07-955	32	3.17	2.60	1.70	1.08	72	7.7	5.2	4.9	35.5	—
098	COTTON <i>Gossypium</i> spp bolls, sun-cured	1-01-596	92	1.94	1.59	0.75	0.22	44	11.0	2.7	7.7	32.2	—
099	hulls	1-01-599	91	1.85	1.52	0.68	0.15	42	4.1	1.7	2.8	47.8	90
100	seeds	5-01-614	92	4.23	3.47	2.41	1.69	96	23.9	23.1	4.8	20.8	39
101	seeds, meal mechanical extracted, 41% protein	5-01-617	93	3.44	2.82	1.88	1.24	78	44.3	5.0	6.6	12.8	26
102	seeds, meal prepressed solvent extracted, 41% protein	5-07-872	91	3.53	2.89	1.94	1.30	80	45.6	1.3	7.0	14.1	26
103	seeds, meal solvent extracted, 41% protein	5-01-621	91	3.35	2.75	1.82	1.19	76	45.2	1.6	7.1	13.3	—
104	seeds without hulls, meal prepressed solvent extracted, 50% protein	5-07-874	93	3.31	2.71	1.79	1.16	75	54.0	1.4	7.1	8.8	—
105	COWPEA, COMMON <i>Vigna sinensis</i> hay, sun-cured	1-01-645	90	2.60	2.13	1.26	0.71	59	19.4	3.1	11.3	26.7	—
	DESERT MOLLY—SEE SUMMER-CYPRUS												
	DISTILLERS GRAINS—SEE CORN, SEE SORGHUM												
	DROPSIDE, SAND <i>Sporobolus cryptandrus</i>												
106	fresh, stem cured	2-05-596	88	2.60	2.13	1.26	0.71	59	5.0	1.4	6.3	—	—
	FATS AND OILS												
107	fat, animal, hydrolyzed	4-00-376	99	7.80	6.40	4.75	3.51	177	—	99.5	—	—	—
108	fat, animal, poultry	4-00-409	99	7.80	6.40	4.75	3.51	177	—	100.0	—	—	—
109	oil, vegetable	4-05-077	100	7.80	6.40	4.75	3.51	177	—	99.9	—	—	—
	FESCUE <i>Festuca</i> spp												
110	hay, sun-cured, early vegetative	1-06-132	91	2.69	2.21	1.34	0.77	61	12.4	3.4	12.0	26.0	57
111	hay, sun-cured, early bloom	1-01-871	92	2.12	1.74	0.90	0.35	48	9.5	2.0	10.0	37.0	72
	FLAX, COMMON <i>Linum usitatissimum</i>												
112	seed screenings	4-02-056	91	2.82	2.31	1.44	0.86	64	18.2	10.2	6.8	13.2	—
113	seeds, meal mechanical extracted (linseed meal)	5-02-045	91	3.62	2.97	2.00	1.35	82	37.9	6.0	6.3	9.6	25
114	seeds, meal solvent extracted (linseed meal)	5-02-048	90	3.44	2.82	1.88	1.24	78	38.3	1.5	6.5	10.1	25
	GALLETA <i>Hilaria jamesii</i>												
115	fresh, stem-cured	2-05-594	71	2.12	1.74	0.90	0.35	48	5.5	1.8	16.2	33.0	—
	GRAMA <i>Bouteloua</i> spp												
116	fresh, early vegetative	2-02-163	41	2.65	2.17	1.31	0.74	60	13.1	2.0	11.3	27.2	—
117	fresh, mature	2-02-166	63	2.43	1.99	1.14	0.58	55	6.5	1.7	11.4	32.7	—
	GRAPE <i>Vitis</i> spp												
118	marc, dehydrated (pomace)	1-02-208	91	1.19	0.98	0.10	—	27	13.0	7.9	10.3	31.9	55
	HEMICELLULOSE EXTRACT (MASONEX)												
119		4-08-030	76	2.65	2.17	1.31	0.74	60	0.7	0.4	4.1	1.0	—
	LESPEDEZA, COMMON-LESPEDEZA, KOREAN <i>Lespedeza striata-Lespedeza stipularis</i>												
120	fresh, late vegetative	2-26-028	32	2.60	2.13	1.26	0.71	59	16.4	—	—	32.0	—
121	fresh, early bloom	2-20-885	28	2.43	1.99	1.14	0.58	55	16.4	—	—	32.0	—
122	hay, sun-cured, early bloom	1-26-025	93	2.43	1.99	1.14	0.58	55	15.5	—	—	28.0	—
123	hay, sun-cured, midbloom	1-26-026	93	2.21	1.81	0.97	0.42	50	14.5	—	—	30.0	—
124	hay, sun-cured, full bloom	1-26-027	93	2.07	1.70	0.86	0.32	47	13.4	—	—	32.0	—
	LIGNIN SULFONATE, CALCIUM												
125	dehydrated	8-16-028	97	0.35	0.29	—	—	8	0.5	0.5	4.0	1.0	—
	LINSEED—SEE FLAX												
	MEADOW PLANTS, INTERMOUNTAIN												
126	hay, sun-cured	1-03-181	95	2.56	2.10	1.24	0.68	58	8.7	2.5	8.5	32.3	—
	MILLET, FOXTAIL <i>Setaria italica</i>												
127	fresh	2-03-101	28	2.78	2.28	1.41	0.83	63	9.5	3.1	8.7	31.6	—
128	grain	4-03-102	89	3.75	3.07	2.09	1.43	85	13.5	4.6	4.0	9.3	—
129	hay, sun-cured	1-03-099	87	2.60	2.13	1.26	0.71	59	8.6	2.9	8.6	29.6	—
	MILLET, PROSO <i>Panicum miliaceum</i>												
130	grain	4-03-120	90	3.70	3.04	2.06	1.40	84	12.9	3.9	2.9	6.8	—

Entry Number	Acid Detergent Fiber (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Carotene (Provitamin A) Vitamin A Activity (1000 IU/kg)
093	55	—	47	7	0.38	—	0.31	0.31	1.54	0.03	0.11	—	—	—	—	—	—	—	6.0
094	—	—	—	—	0.34	—	0.23	0.19	1.41	—	0.06	—	—	—	—	—	—	—	5.0
095	28	—	—	—	0.23	—	0.19	0.22	0.96	0.01	0.15	0.06	10	—	280	30	—	21	18.0
096	—	—	—	—	0.30	—	0.24	0.72	1.15	0.03	0.13	—	7	—	200	—	—	—	5.4
097	—	—	—	—	0.30	—	0.24	0.90	1.15	0.03	0.11	—	—	—	200	—	—	—	5.4
098	—	—	—	—	0.90	—	0.28	0.12	2.73	—	—	—	—	—	—	—	—	—	—
099	64	—	40	24	0.15	0.02	0.14	0.09	0.67	0.02	0.09	0.02	13	—	131	119	—	22	—
100	29	—	—	—	0.16	—	0.35	0.75	1.21	0.31	0.26	—	54	—	151	10	—	—	—
101	20	—	13	6	0.21	0.05	0.58	1.16	1.45	0.05	0.43	0.17	20	—	197	24	—	69	0.1
102	19	—	12	6	0.22	0.04	0.55	1.21	1.39	0.04	0.34	0.82	20	—	223	23	—	69	—
103	17	—	12	—	0.18	0.05	0.59	1.21	1.52	0.05	0.28	0.17	22	—	228	23	—	68	—
104	—	—	—	—	0.19	0.05	0.50	1.24	1.56	0.06	0.56	0.05	16	—	120	25	—	79	—
105	—	—	—	—	1.40	0.17	0.45	0.35	2.26	0.27	0.35	0.07	—	—	300	—	—	—	14.0
106	—	—	—	6	0.57	—	0.06	0.06	0.32	0.01	—	0.57	15	0.68	482	47	—	42	0.4
107	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
108	—	—	—	—	—	—	—	—	0.23	—	—	—	—	—	—	—	—	—	—
109	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
110	32	—	26	3	0.51	—	0.22	0.36	2.30	—	—	—	—	—	100	—	—	—	—
111	39	—	33	5	0.30	—	0.19	0.26	1.70	—	—	—	—	—	—	—	—	—	—
112	—	—	—	—	0.37	—	0.43	0.47	0.84	—	0.25	—	—	—	190	—	—	—	—
113	17	—	—	7	0.45	0.04	0.64	0.96	1.34	0.12	0.41	0.46	29	0.07	194	42	0.89	36	0.1
114	19	—	—	6	0.43	0.04	0.66	0.89	1.53	0.15	0.43	0.21	29	—	354	42	0.91	—	—
115	—	—	—	—	1.05	—	0.10	0.07	1.00	0.01	0.10	0.69	19	—	100	79	—	23	0.1
116	—	—	—	—	0.53	—	—	0.19	—	—	—	—	6	—	—	44	—	—	—
117	—	—	—	—	0.34	—	—	0.12	0.35	—	—	0.18	13	—	1300	47	—	—	12.2
118	54	—	—	35	0.61	0.01	—	0.06	0.62	0.09	—	—	—	—	—	41	—	24	—
119	—	—	—	—	1.03	—	—	0.09	—	—	—	—	—	—	—	—	—	—	—
120	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	103.0
121	—	—	—	—	1.35	—	0.27	0.21	1.12	—	—	—	—	—	250	—	—	—	—
122	—	—	—	—	1.23	—	0.26	0.25	1.00	—	—	0.04	0	—	400	256	—	—	55.0
123	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	22.0
124	—	—	—	—	—	—	0.24	—	—	—	—	—	—	—	—	—	—	—	5.0
125	—	—	—	76	3.75	—	—	0.07	—	—	4.50	—	—	—	—	—	—	—	—
126	—	—	—	—	0.61	—	0.17	0.18	1.58	0.12	—	—	—	—	—	—	—	—	13.4
127	—	—	—	—	0.32	—	—	0.19	1.94	—	—	—	—	—	—	—	—	—	—
128	—	—	—	—	—	—	—	0.22	0.35	—	—	—	—	—	—	—	—	—	—
129	—	—	—	—	0.33	0.13	0.23	0.19	1.94	0.10	0.16	—	—	—	—	136	—	—	24.0
130	17	—	—	4	0.03	—	0.18	0.34	0.45	—	—	—	—	—	79	—	—	—	—

54 Nutrient Requirements of Beef Cattle

TABLE 8 Composition of Some Beef Cattle Feeds—Continued

Dry Basis (100% Dry Matter)														
Entry Number	Feed Name Description	International Feed Number*	Dry Matter (%)	DE (Mcal/kg)	ME (Mcal/kg)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	TDN (%)	Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)	Cell Walls (%)	
MOLASSES AND SYRUP <i>Beta vulgaris altissima</i>														
131	beet, sugar, molasses, more than 48% invert sugar, more than 79.5 de-greens bits	4-00-668	78	3.48	2.86	1.91	1.27	79	8.5	0.2	11.3	—	—	
MOLASSES AND SYRUP <i>Citrus</i> spp MOLASSES AND SYRUP <i>Saccharum officinarum</i>														
132	citrus, syrup (citrus molasses)	4-01-841	68	3.31	2.71	1.79	1.16	75	8.2	0.3	7.9	—	—	
133	sugarcane, molasses, dehydrated	4-04-695	94	3.09	2.53	1.63	1.03	70	10.3	0.9	13.3	6.7	—	
134	sugarcane, molasses, more than 46% invert sugar, more than 79.5 de-greens bits (black strap)	4-04-696	75	3.17	2.60	1.70	1.08	72	5.8	0.1	13.1	0.5	—	
NAPIERGRASS <i>Pennisetum purpureum</i>														
135	fresh, late vegetative	2-03-158	30	2.43	1.99	1.14	0.58	55	8.7	3.0	8.6	33.0	70	
136	fresh, late bloom	2-03-162	23	2.34	1.92	1.07	0.52	53	7.8	1.1	5.3	39.0	75	
NEEDLEANDTHREAD <i>Stipa comata</i>														
137	fresh, stem cured	2-07-989	92	2.16	1.77	0.93	0.39	49	4.1	5.4	21.1	—	83	
OATS <i>Avena sativa</i>														
138	grain	4-03-309	89	3.40	2.78	1.85	1.22	77	13.3	5.4	3.4	12.1	32	
139	grain, pacific coast	4-07-999	91	3.44	2.82	1.88	1.24	78	10.0	5.5	4.2	12.3	—	
140	groats	4-03-331	90	4.14	3.40	2.35	1.65	94	17.7	6.9	2.4	2.8	—	
141	hay, sun-cured	1-03-280	91	2.43	1.99	1.14	0.58	55	9.3	2.6	7.6	30.4	66	
142	hulls	1-03-281	92	1.54	1.27	0.41	—	35	3.9	1.8	6.6	33.4	78	
143	silage, late vegetative	3-30-808	23	2.87	2.35	1.47	0.88	65	12.8	2.5	6.5	29.9	58	
144	silage, dough stage	3-03-296	35	2.51	2.06	1.21	0.64	57	10.0	4.1	6.9	33.0	—	
145	straw	1-03-283	92	1.98	1.63	0.79	0.25	45	4.4	2.2	7.8	40.5	70	
ORCHARDGRASS <i>Dactylis glomerata</i>														
146	fresh, early vegetative	2-03-439	23	3.17	2.60	1.70	1.08	72	18.4	4.9	11.3	24.7	55	
147	fresh, midbloom	2-03-443	31	2.51	2.06	1.21	0.64	57	11.0	3.5	7.5	33.5	68	
148	hay, sun-cured, early bloom	1-03-425	89	2.87	2.35	1.47	0.88	65	15.0	2.8	8.7	31.0	61	
149	hay, sun-cured, late bloom	1-03-428	91	2.38	1.95	1.11	0.55	54	8.4	3.4	10.1	37.1	72	
PANGOLAGRASS <i>Digitaria decumbens</i>														
150	fresh	2-03-493	21	2.43	1.99	1.14	0.58	55	10.3	2.3	9.6	30.5	—	
151	hay, sun-cured, 15 to 28 days' growth	1-10-638	91	2.25	1.84	1.00	0.45	51	11.5	2.2	8.5	34.0	70	
152	hay, sun-cured, 29 to 42 days' growth	1-26-214	91	1.98	1.63	0.79	0.25	45	7.1	2.0	8.0	36.0	73	
153	hay, sun-cured, 43 to 56 days' growth	1-29-573	91	1.76	1.45	0.60	0.08	40	5.5	2.0	7.6	38.0	77	
PEA <i>Plum</i> spp														
154	seeds	5-03-800	89	3.84	3.15	2.15	1.48	87	25.3	1.4	3.3	6.9	—	
155	straw	1-03-577	87	2.03	1.66	0.83	0.29	46	8.9	1.6	6.5	39.5	—	
156	vines without seeds, silage	3-03-506	25	2.51	2.06	1.21	0.64	57	13.1	3.3	9.0	29.8	59	
PEANUT <i>Arachis hypogaea</i>														
157	hay, sun-cured	1-03-619	91	2.43	1.99	1.14	0.58	55	10.8	3.4	8.6	33.2	—	
158	hulls (pods)	1-08-028	91	0.97	0.80	—	—	22	7.8	2.0	4.2	62.9	74	
159	kernels, meal mechanical extracted (peanut meal)	5-03-649	93	3.66	3.00	2.03	1.37	83	52.0	6.3	5.5	7.5	14	
160	kernels, meal solvent extracted (peanut meal)	5-03-650	92	3.40	2.78	1.85	1.22	77	52.3	1.4	6.3	10.8	—	
PEARLMILLET <i>Pennisetum glaucum</i>														
161	fresh	2-03-115	21	2.89	2.21	1.34	0.77	61	8.5	2.2	10.0	31.5	—	
PINEAPPLE <i>Ananas comosus</i>														
162	aerial part without fruit, sun-cured (pineapple hay)	1-13-309	89	2.69	2.21	1.34	0.77	61	7.8	2.8	6.1	29.6	—	
163	process residue, dehydrated (pineapple bran)	4-03-722	87	3.00	2.46	1.57	0.97	68	4.6	1.5	3.5	20.9	73	
POTATO <i>Solanum tuberosum</i>														
164	process residue, dehydrated	4-03-775	89	3.97	3.25	2.24	1.55	90	8.4	0.4	3.4	7.3	—	
165	tubers, fresh	4-03-787	23	3.57	2.93	1.97	1.32	81	9.5	0.4	4.8	2.4	—	
166	tubers, silage	4-03-798	25	3.62	2.97	2.00	1.35	82	7.6	0.4	5.5	4	—	
POULTRY														
167	feathers, hydrolyzed	5-03-795	93	3.09	2.53	1.63	1.03	70	91.3	3.2	3.8	1.5	—	
168	manure, dehydrated	5-14-015	90	2.29	1.88	1.04	0.49	52	28.2	2.4	30.1	13.2	38	
169	manure and litter, dehydrated	5-05-587	89	2.91	2.39	1.51	0.91	66	24.5	3.0	22.0	16.1	—	
PRAIRIE PLANTS, MIDWEST														
170	hay, sun-cured	1-03-191	92	2.25	1.84	1.00	0.45	51	5.8	2.4	7.1	34.0	—	
RAPE <i>Brassica napus</i>														
171	fresh, early bloom	2-03-866	11	3.31	2.71	1.79	1.16	75	23.5	3.8	14.0	15.8	—	
172	seeds, meal mechanical extracted	5-03-870	92	3.35	2.75	1.82	1.19	76	38.7	7.9	7.5	13.1	—	
173	seeds, meal solvent extracted	5-03-871	91	3.04	2.50	1.60	1.00	69	40.6	1.8	7.5	13.2	—	

Entry Number	Acid Detergent Fiber (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Carotene (Provitamin A) Activity (1000 IU/kg)
131	—	—	—	—	0.17	1.64	0.29	0.03	6.07	1.48	0.60	0.46	22	—	87	6	—	18	—
132	—	—	—	—	1.72	0.11	0.21	0.13	0.14	0.41	0.23	0.16	106	—	508	36	—	137	—
133	—	—	—	—	1.10	—	0.47	0.15	3.60	0.20	0.46	1.21	79	2.10	250	57	—	33	—
134	0	—	—	0	1.00	3.10	0.43	0.11	3.84	0.22	0.47	1.21	79	2.10	250	56	—	30	—
135	45	—	33	10	0.60	—	0.26	0.41	1.31	0.01	0.10	—	—	—	—	—	—	—	—
136	47	—	35	14	0.35	—	0.26	0.30	1.31	0.01	0.10	—	—	—	—	—	—	—	—
137	43	40	36	6	1.08	—	—	0.06	—	—	—	—	—	—	—	—	—	—	—
138	16	15	11	3	0.07	0.11	0.14	0.38	0.44	0.08	0.23	0.06	7	0.11	85	42	0.26	41	0.0
139	—	—	—	—	0.11	0.13	0.19	0.34	0.42	0.07	0.22	—	—	—	80	42	0.06	—	—
140	—	—	—	—	0.08	0.09	0.13	0.48	0.39	0.06	0.22	—	7	0.12	82	31	—	0	—
141	36	26	—	6	0.24	0.52	0.26	0.22	1.51	0.18	0.25	0.07	15	—	155	64	0.17	39	11.1
142	42	—	30	8	0.15	0.06	0.06	0.15	0.62	0.04	0.15	—	4	—	111	20	—	—	—
143	—	—	—	—	—	—	—	0.10	2.44	0.37	0.24	—	—	—	—	—	—	—	65.0
144	—	—	—	—	0.47	—	—	0.33	—	—	—	—	—	—	—	—	—	—	24.0
145	54	—	40	14	0.24	0.78	0.18	0.06	2.57	0.42	0.23	—	10	—	175	37	—	6	1.5
146	31	24	25	3	0.58	0.08	0.31	0.54	3.58	0.04	0.21	—	7	—	169	96	—	—	192.8
147	41	27	33	6	0.23	—	—	0.23	—	—	—	—	—	—	—	—	—	—	—
148	34	27	29	5	0.27	—	0.11	0.34	2.91	0.01	—	0.43	18	—	93	158	—	40	15.0
149	45	27	39	9	0.28	—	0.11	0.30	2.67	0.01	—	0.30	20	—	84	168	—	38	8.0
150	38	—	35	5	0.43	—	0.14	0.18	1.43	—	—	—	—	—	—	—	—	—	24.8
151	41	—	33	6	0.58	—	0.20	0.21	1.70	—	—	—	—	—	—	—	—	—	—
152	43	—	35	6	0.46	—	0.15	0.23	1.40	—	—	—	—	—	—	—	—	—	—
153	46	—	37	7	0.38	—	0.14	0.18	1.10	—	—	—	—	—	—	—	—	—	—
154	—	—	—	—	0.15	0.06	0.14	0.44	1.13	0.05	—	—	—	—	57	—	—	33	0.3
155	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
156	49	—	34	9	1.31	—	0.39	0.24	1.40	0.01	0.25	—	—	—	100	—	—	—	75.6
157	—	—	—	—	1.23	—	0.49	0.15	1.38	—	0.23	0.06	—	—	—	—	—	—	13.9
158	65	—	40	23	0.26	—	0.17	0.07	0.95	0.13	0.10	0.12	18	—	312	69	—	24	0.4
159	6	—	5	—	0.30	0.03	0.31	0.61	1.25	0.23	0.29	0.12	16	0.07	169	28	0.31	22	0.1
160	—	—	—	—	0.29	0.03	0.17	0.68	1.23	0.08	0.33	0.12	17	0.07	154	29	—	22	—
161	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	73.0
162	—	—	—	—	0.39	—	—	0.23	—	—	—	—	—	—	—	—	—	—	—
163	37	—	—	7	0.23	—	—	0.13	—	—	—	—	—	—	561	—	—	—	21.6
164	—	—	—	—	0.16	—	—	0.25	—	—	—	—	—	—	—	—	—	—	—
165	—	—	—	—	0.04	0.28	0.14	0.24	2.17	0.09	0.09	—	26	—	78	42	—	—	—
166	—	—	—	—	0.04	—	0.14	0.23	2.13	0.09	0.23	—	—	—	90	—	—	—	—
167	—	—	—	—	0.28	0.30	0.22	0.72	0.31	0.76	1.61	0.05	7	0.05	81	14	0.90	74	—
168	15	—	2	—	9.31	0.95	0.64	2.52	0.74	0.18	0.00	89	—	—	3000	406	—	434	—
169	—	—	9	—	3.16	—	0.50	1.78	1.68	0.51	1.26	—	192	—	778	289	0.79	444	—
170	—	—	—	—	0.43	0.06	0.29	0.15	1.08	0.04	—	0.13	7	—	129	110	—	34	9.8
171	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
172	—	—	—	—	0.72	—	0.54	1.14	0.90	0.50	—	—	7	—	190	60	1.04	47	—
173	—	—	—	—	0.67	0.11	0.60	1.04	1.36	0.10	1.25	—	—	—	—	—	1.07	—	—

TABLE 8 Composition of Some Beef Cattle Feeds—Continued

Entry Number	Feed Name Description	Internal Feed Number ^a	Dry Basis (100% Dry Matter)										Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)	Cell Walls (%)
			Dry Matter (%)	DE (Mcal/kg)	ME (Mcal/kg)	NE _{int} (Mcal/kg)	NE _E (Mcal/kg)	TDN (%)	Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)					
174	REDTOP <i>Agrostis alba</i> fresh	2-03-897	29	2.78	2.28	1.41	0.83	63	11.6	3.9	8.1	26.7	64	—	—	—	—
175	hay, sun-cured, midbloom	1-03-886	94	2.51	2.06	1.21	0.64	57	11.7	2.6	6.5	30.7	—	—	—	—	—
176	RICE <i>Oryza sativa</i> bran with germs (rice, bran)	4-03-928	91	3.09	2.53	1.63	1.03	70	14.1	15.1	12.8	12.6	33	—	—	—	—
177	grain, ground (ground rough rice) (ground paddy rice)	4-03-938	89	3.48	2.86	1.91	1.27	79	8.9	1.9	5.3	10.0	—	—	—	—	—
178	hulls	1-08-075	92	0.33	0.43	—	—	12	3.3	0.8	20.6	42.9	82	—	—	—	—
179	straw	1-03-925	91	1.81	1.48	0.64	0.11	41	4.3	1.4	17.0	35.1	71	—	—	—	—
180	RYE <i>Secale cereale</i> distillers grains, dehydrated	5-04-023	92	2.69	2.21	1.34	0.77	61	23.5	7.8	2.5	13.4	—	—	—	—	—
181	fresh	2-04-018	24	3.04	2.50	1.60	1.00	69	15.9	3.7	8.1	28.5	—	—	—	—	—
182	grain	4-04-047	88	3.70	3.04	2.06	1.40	84	13.8	1.7	1.9	2.5	—	—	—	—	—
183	mill run, less than 9.5% fiber (rye feed)	4-04-034	90	3.31	2.71	1.79	1.16	75	18.5	3.7	4.2	5.1	—	—	—	—	—
184	straw	1-04-007	90	1.37	1.12	0.26	—	31	3.0	1.7	5.0	43.1	—	—	—	—	—
185	RYEGRASS, ITALIAN <i>Lolium multiflorum</i> fresh	2-04-073	25	2.65	2.17	1.31	0.74	60	14.5	3.2	14.0	23.8	—	—	—	—	—
186	hay, sun-cured, late vegetative	1-04-065	86	2.73	2.24	1.38	0.80	62	10.3	2.4	11.0	23.8	—	—	—	—	—
187	hay, sun-cured, early bloom	1-04-066	83	2.38	1.95	1.11	0.55	54	5.5	0.9	8.4	36.3	—	—	—	—	—
188	RYEGRASS, PERENNIAL <i>Lolium perenne</i> fresh	2-04-086	27	3.00	2.46	1.57	0.97	68	10.4	2.7	8.6	23.2	—	—	—	—	—
189	hay, sun-cured	1-04-077	86	2.65	2.17	1.31	0.74	60	8.6	2.2	11.5	30.3	41	—	—	—	—
190	SAFFLOWER <i>Carthamus tinctorius</i> seeds	4-07-958	94	3.92	3.22	2.21	1.52	89	17.4	35.1	3.1	28.6	—	—	—	—	—
191	seeds, meal mechanical extracted	5-04-109	91	2.65	2.17	1.31	0.74	60	22.1	6.7	4.1	35.4	59	—	—	—	—
192	seeds, meal solvent extracted	5-04-110	92	2.51	2.06	1.21	0.64	57	25.4	1.5	5.9	32.5	58	—	—	—	—
193	seeds without hulls, meal solvent extracted	5-07-959	92	3.22	2.64	1.73	1.11	73	46.9	1.4	8.2	14.7	—	—	—	—	—
194	SAGE, BLACK <i>Salvia mellifera</i> browse, fresh, stem-cured	2-05-564	65	2.16	1.77	0.93	0.39	49	8.5	10.8	5.5	—	—	—	—	—	—
195	SAGEBRUSH, BIG <i>Artemisia tridentata</i> browse, fresh, stem-cured	2-07-992	65	2.21	1.81	0.97	0.42	50	9.3	11.0	6.6	—	42	—	—	—	—
196	SAGEBRUSH, BUD <i>Artemisia spinescens</i> browse, fresh, early vegetative	2-07-991	23	2.25	1.84	1.00	0.45	51	17.3	4.9	21.4	—	—	—	—	—	—
197	hay, sun-cured	2-04-124	32	2.29	1.88	1.04	0.49	52	17.5	2.5	21.6	22.7	—	—	—	—	—
198	SAGEBRUSH, FRINGED <i>Artemisia frigida</i> browse, fresh, midbloom	2-04-129	43	2.56	2.10	1.24	0.68	58	9.4	2.0	6.5	33.2	—	—	—	—	—
199	browse, fresh, mature	2-04-130	60	2.25	1.84	1.00	0.45	51	7.1	3.4	17.1	31.8	46	—	—	—	—
200	SALTBUSH, NUTTALL <i>Atriplex nuttallii</i> browse, fresh, stem-cured	2-07-993	55	1.59	1.30	0.45	—	36	7.2	2.2	21.5	—	—	—	—	—	—
201	SALTGRASS <i>Distichlis</i> spp. fresh, post ripe	2-04-169	74	2.34	1.92	1.07	0.52	53	4.2	2.6	7.3	34.9	—	—	—	—	—
202	hay, sun-cured	1-04-168	89	2.25	1.84	1.00	0.45	51	8.9	2.1	12.7	31.6	—	—	—	—	—
203	SEAWEED, KELP <i>Laminariales</i> (order): <i>Fucales</i> (order) whole, dehydrated	4-06-073	91	1.41	1.16	0.30	—	32	7.1	0.5	38.6	7.1	—	—	—	—	—
204	SEDGE <i>Carex</i> spp. hay, sun-cured	1-04-193	89	2.29	1.88	1.04	0.49	52	9.4	2.4	7.2	31.3	—	—	—	—	—
205	SESAME <i>Sesamum indicum</i> seeds, meal mechanical extracted	5-04-220	93	3.40	2.78	1.85	1.22	77	49.1	7.5	12.1	6.1	17	—	—	—	—
206	SOLKA FLOC	1-28-258	93	3.09	2.53	1.63	1.03	70	—	—	—	—	99	—	—	—	—
207	SORCHUM <i>Sorghum bicolor</i> aerial part with heads, sun-cured (fodder)	1-07-980	89	2.56	2.10	1.24	0.68	58	7.5	2.4	9.4	26.9	—	—	—	—	—
208	aerial part without heads, sun-cured (stover)	1-04-302	88	2.38	1.95	1.11	0.55	54	5.2	1.7	11.0	33.5	—	—	—	—	—
209	distillers grains, dehydrated	5-04-374	94	3.66	3.00	2.03	1.37	83	34.4	9.5	3.8	12.7	—	—	—	—	—
210	grain, less than 8% protein	4-20-892	88	3.75	3.07	2.09	1.43	85	7.7	3.0	—	2.2	—	—	—	—	—
211	grain, 8-10% protein	4-20-893	87	3.70	3.04	2.06	1.40	84	10.1	3.4	2.1	2.6	—	—	—	—	—
212	grain, more than 10% protein	4-20-894	88	3.66	3.00	2.03	1.37	83	12.5	2.4	2.1	2.6	—	—	—	—	—
213	grain, flaked	4-16-295	85	4.06	3.33	2.30	1.60	92	—	—	—	—	—	—	—	—	—
214	grain, reconstituted	4-16-296	70	4.10	3.36	2.33	1.62	93	—	—	—	—	—	—	—	—	—
215	silage	3-04-323	30	2.65	2.17	1.31	0.74	60	7.5	3.0	8.7	27.9	—	—	—	—	—

Entry Number	Acid Detergent Fiber (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Carotene (Provitamin A) Vitamin A Activity (1000 IU/kg)
174	—	19	—	8	0.48	0.09	0.23	0.29	2.35	0.05	0.19	—	26	—	200	—	—	—	86.9
175	—	—	—	—	0.63	—	—	0.35	1.89	—	—	—	—	—	—	—	—	—	2.0
176	18	15	11	4	0.08	0.08	1.04	1.70	1.92	0.04	0.20	—	15	—	210	415	0.44	32	—
177	—	—	—	—	0.07	0.09	0.15	0.32	0.36	0.06	0.05	0.05	3	0.05	57	—	—	17	—
178	49	—	33	16	0.10	0.08	0.83	0.08	0.57	0.12	0.09	—	—	—	—	334	—	—	—
179	55	—	—	5	0.21	—	0.11	0.08	1.32	0.31	—	—	—	—	—	346	—	—	—
180	—	—	—	—	0.16	0.05	0.18	0.52	0.08	0.18	0.48	—	—	—	—	30	—	—	—
181	—	—	—	—	0.39	—	0.31	0.33	3.40	0.07	—	—	—	—	—	—	—	—	137.0
182	—	—	—	—	0.07	0.03	0.14	0.37	0.52	0.03	0.17	—	8	—	69	66	0.44	36	0.0
183	—	—	—	—	0.08	—	0.28	0.71	0.92	—	0.04	—	—	—	—	—	—	—	—
184	—	—	—	—	0.24	0.24	0.08	0.09	0.97	0.13	0.11	—	4	—	—	7	—	—	—
185	—	—	—	—	0.65	—	0.35	0.41	2.00	0.01	0.10	—	—	—	650	—	—	—	160.4
186	—	—	—	—	0.62	—	—	0.34	1.56	—	—	—	—	—	320	—	—	—	116.0
187	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
188	—	—	—	—	0.55	—	—	0.27	1.91	—	0.30	0.06	13	—	—	—	—	—	88.8
189	30	—	—	2	0.65	—	—	0.32	1.87	—	—	—	—	—	—	—	—	—	48.0
190	—	—	—	—	0.26	—	0.36	0.67	0.79	0.06	—	—	11	—	500	20	—	—	—
191	41	—	—	—	0.27	—	0.36	0.78	0.79	0.05	—	—	11	—	515	20	—	—	—
192	41	—	—	14	0.37	—	0.37	0.81	0.82	0.05	0.14	—	11	—	537	20	—	44	—
193	—	—	—	—	0.36	0.18	1.11	1.40	1.19	0.05	0.22	2.15	9	—	528	43	—	36	—
194	—	—	—	—	0.81	—	—	0.17	—	—	—	—	—	—	—	—	—	—	—
195	30	—	—	12	0.71	—	—	0.18	—	—	—	—	—	—	—	—	—	—	6.4
196	—	—	—	—	0.97	—	—	0.33	—	—	—	—	—	—	—	—	—	—	9.5
197	—	—	—	—	0.60	—	0.49	0.42	—	—	—	—	—	—	—	—	—	—	—
198	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
199	35	—	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
200	—	—	—	—	2.21	—	—	0.12	—	—	—	—	—	—	—	—	—	—	7.6
201	—	—	—	—	0.23	—	0.30	0.07	—	—	—	—	—	—	—	—	—	—	—
202	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
203	—	—	—	—	2.72	—	0.93	0.31	—	—	—	—	—	—	—	—	—	—	—
204	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—
205	17	—	—	2	2.17	0.07	0.50	1.46	1.35	0.04	0.35	—	—	—	100	52	—	108	0.2
206	79	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
207	—	—	—	—	0.40	—	0.29	0.21	1.47	0.02	—	—	—	—	—	—	—	—	20.7
208	46	—	41	6	0.52	—	0.28	0.13	1.20	0.02	—	—	—	—	—	—	—	—	9.1
209	—	—	—	—	0.16	—	0.19	0.74	0.38	0.05	0.18	—	—	—	50	—	—	—	—
210	—	—	—	—	0.03	—	0.19	0.32	0.38	0.05	0.18	—	—	—	50	—	—	—	—
211	—	—	—	—	0.04	—	0.18	0.34	0.40	0.01	0.09	—	—	—	—	17	—	—	—
212	—	—	—	—	0.04	—	0.14	0.36	0.38	0.01	0.13	—	—	—	—	—	—	—	—
213	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
214	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
215	38	—	—	6	0.35	0.13	0.29	0.21	1.37	0.02	0.11	0.30	35	—	285	73	0.22	32	6.2

TABLE 8 Composition of Some Beef Cattle Feeds—Continued

Dry Basis (100% Dry Matter)														
Entry Number	Feed Name Description	Internal Feed Number*	Dry Matter (%)	DE (Mcal/kg)	ME (Mcal/kg)	NE _m (Mcal/kg)	NE _g (Mcal/kg)	TDN (%)	Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)	Cell Walls (%)	
216	SORGHUM, JOHNSONGRASS <i>Sorghum halepense</i> hay, sun-cured	1-04-407	89	2.34	1.92	1.07	0.52	53	9.5	2.4	8.2	33.5	—	
217	SORGHUM, SORGO <i>Sorghum bicolor saccharatum</i> silage	3-04-468	27	2.56	2.10	1.24	0.68	58	6.2	2.6	6.4	28.3	—	
218	SORGHUM, SUDANGRASS <i>Sorghum bicolor sudanense</i> fresh, early vegetative	2-04-484	18	3.09	2.53	1.63	1.03	70	16.8	3.9	9.0	23.0	55	
219	fresh, midbloom	2-04-485	23	2.78	2.28	1.41	0.83	63	8.8	1.8	10.5	30.0	65	
220	hay, sun-cured	1-04-480	91	2.47	2.03	1.18	0.61	56	8.0	1.8	9.6	36.0	68	
221	silage	3-04-499	28	2.43	1.99	1.14	0.58	55	10.8	2.8	9.8	33.1	—	
222	SOYBEAN <i>Glycine max</i> hay, sun-cured, midbloom	1-04-538	94	2.34	1.92	1.07	0.52	53	17.8	5.4	8.8	29.8	—	
223	hulls (seed coats)	1-04-560	91	2.82	2.31	1.44	0.66	64	12.1	2.1	5.1	40.1	67	
224	seeds	5-04-610	92	4.01	3.29	2.27	1.57	91	42.8	18.8	5.5	5.8	—	
225	seeds, meal mechanical extracted	5-04-600	90	3.75	3.07	2.09	1.43	85	47.7	5.3	6.7	6.8	—	
226	seeds, meal solvent extracted, 44% protein	5-20-637	89	3.70	3.04	2.06	1.40	84	49.9	1.5	7.3	7.0	—	
227	seeds without hulls, meal solvent extracted	5-04-612	90	3.84	3.15	2.15	1.48	87	55.1	1.0	6.5	3.7	8	
228	silage	3-04-581	27	2.43	1.99	1.14	0.58	55	17.3	2.7	9.7	28.4	—	
229	straw	1-04-567	88	1.85	1.52	0.68	0.15	42	5.2	1.5	6.4	44.3	70	
230	SPELLT <i>Triticum spelta</i> grain	4-04-651	90	3.31	2.71	1.79	1.18	75	13.3	2.1	3.9	10.2	—	
231	SQUIRRELTAIL <i>Sitanion spp</i> fresh, stem-cured	2-05-566	50	2.21	1.81	0.97	0.42	50	3.1	2.2	17.0	—	—	
232	SUGARCANE <i>Saccharum officinarum</i> bagasse, dehydrated	1-04-666	91	2.12	1.74	0.90	0.35	48	1.6	0.7	3.2	48.1	87	
233	MOLASSES—SEE MOLASSES AND SYRUP													
234	stems, fresh	2-13-248	15	2.69	2.21	1.34	0.77	61	7.6	0.7	6.0	27.5	74	
235	sugar	4-04-701	100	4.32	3.54	2.47	1.74	98	—	—	0.1	—	—	
236	SUMMERCYPRESS, GRAY <i>Kochia cordata</i> fresh, stem-cured	2-08-643	85	2.21	1.81	0.97	0.42	50	9.0	3.7	24.8	22.0	—	
237	SUNFLOWER, COMMON <i>Helianthus annuus</i> seeds, meal solvent extracted	5-09-340	90	1.94	1.59	0.75	0.22	44	25.9	1.2	6.3	35.1	40	
238	seeds without hulls, meal mechanical extracted	5-04-738	93	3.26	2.68	1.76	1.14	74	44.8	8.7	7.1	13.1	—	
239	seeds without hulls, meal solvent extracted	5-04-739	93	2.87	2.35	1.47	0.88	65	49.8	3.1	8.1	12.2	—	
240	SWEETCLOVER, YELLOW <i>Melilotus officinalis</i> hay, sun-cured	1-04-754	87	2.38	1.95	1.11	0.55	54	15.7	2.0	8.8	33.4	—	
241	TIMOTHY <i>Phleum pratense</i> fresh, late vegetative	2-04-903	26	3.17	2.80	1.70	1.06	72	18.0	3.8	8.8	32.1	—	
242	fresh, midbloom	2-04-905	29	2.78	2.28	1.41	0.83	63	9.1	3.0	6.6	33.5	64	
243	hay, sun-cured, late vegetative	1-04-881	89	2.73	2.24	1.38	0.80	62	17.0	2.8	7.1	27.0	35	
244	hay, sun-cured, early bloom	1-04-882	90	2.60	2.13	1.28	0.71	59	15.0	2.9	5.7	28.0	61	
245	hay, sun-cured, midbloom	1-04-883	89	2.51	2.06	1.21	0.64	57	9.1	2.6	6.3	31.0	67	
246	hay, sun-cured, full bloom	1-04-884	89	2.47	2.03	1.18	0.61	56	8.1	3.1	5.2	32.0	68	
247	silage, full bloom	3-04-920	36	2.47	2.03	1.18	0.61	56	9.7	3.2	6.9	36.3	—	
248	TOMATO <i>Lycopersicon esculentum</i> pomace, dehydrated	5-05-041	92	2.56	2.10	1.24	0.68	58	23.5	10.3	7.5	26.4	55	
249	TREFOIL, BIRDSFOOT <i>Lotus corniculatus</i> fresh	2-20-786	24	2.91	2.39	1.51	0.91	66	21.0	2.7	9.0	24.7	—	
250	hay, sun-cured	1-05-044	92	2.60	2.13	1.28	0.71	59	16.3	2.5	7.0	30.7	47	
251	TRITICALE <i>Triticale hexaploide</i> grain	4-20-362	90	3.70	3.04	2.06	1.40	84	17.6	1.7	2.0	4.4	—	
252	TURNIP <i>Brassica rapa rapa</i> roots, fresh	4-05-067	9	3.75	3.07	2.09	1.43	85	11.8	1.9	8.9	11.5	44	
253	UREA 45% nitrogen, 28% protein equivalent	5-05-070	99	—	—	—	—	—	287.0	—	—	—	—	
254	VETCH <i>Vicia spp</i> hay, sun-cured	1-05-106	89	2.51	2.06	1.21	0.64	57	20.8	3.0	9.1	30.6	48	

Entry Number	Acid Detergent Fiber (%)	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Candene (Provitamin A) Vitamin A Activity (1000 IU/kg)
216	—	—	—	—	0.84	—	0.35	0.28	1.35	0.01	0.10	—	—	—	590	—	—	—	15.6
217	—	—	—	—	0.34	0.06	0.27	0.17	1.12	0.15	0.10	—	31	—	198	61	—	—	14.5
218	29	34	26	3	0.43	—	0.35	0.41	2.14	0.01	0.11	—	—	—	200	—	—	—	79.0
219	40	25	34	5	0.43	—	0.35	0.38	2.14	0.01	0.11	—	—	—	200	—	—	—	73.0
220	42	26	35	6	0.55	—	0.51	0.30	1.87	0.02	0.06	0.13	37	—	193	91	—	38	23.5
221	42	—	38	5	0.46	—	0.44	0.21	2.25	0.02	0.06	0.31	37	—	127	99	—	—	42.1
222	—	—	—	—	1.26	—	0.70	0.27	0.97	0.12	0.26	—	—	—	300	—	—	—	13.3
223	50	18	46	2	0.49	—	0.21	1.27	0.01	0.09	0.12	18	—	—	324	11	—	24	—
224	10	—	—	—	0.27	0.03	0.29	0.63	1.62	0.02	0.24	—	20	—	91	39	0.12	62	0.4
225	—	—	—	—	0.29	0.06	0.26	0.68	1.98	0.03	0.37	0.30	24	—	175	35	0.11	66	0.1
226	—	—	—	—	0.33	—	0.30	0.71	2.14	0.03	0.47	0.10	30	—	142	32	0.14	61	—
227	6	—	5	—	0.29	0.05	0.32	0.70	2.30	0.03	0.48	0.07	22	0.12	148	41	0.11	61	—
228	—	—	—	—	1.36	—	0.38	0.47	0.93	0.09	0.30	—	9	—	400	114	—	34	41.5
229	54	—	38	16	1.59	—	0.92	0.06	0.56	0.12	0.26	—	—	—	300	51	—	—	—
230	—	—	—	—	0.13	—	—	0.42	—	—	—	—	—	—	—	—	—	—	—
231	—	—	—	—	0.37	—	—	0.06	—	—	—	—	—	—	—	—	—	—	—
232	60	—	—	14	0.90	—	0.10	0.29	0.50	0.20	0.10	—	—	—	100	—	—	—	—
233	—	30	34	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
234	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
235	—	—	—	—	2.36	—	—	0.12	—	—	—	—	—	—	—	—	—	—	7.2
236	33	—	—	12	0.23	—	0.75	1.03	1.06	—	0.33	—	—	—	—	—	—	—	—
237	—	—	—	—	0.42	0.20	0.78	1.14	1.14	0.24	—	—	4	—	33	22	—	—	—
238	—	—	—	—	0.44	0.11	0.77	0.98	1.14	0.24	—	—	4	—	33	20	—	—	—
239	—	—	—	—	1.27	0.37	0.49	0.25	1.60	0.09	0.47	—	10	—	152	108	—	—	39.5
240	—	—	—	—	—	0.39	—	0.15	0.32	2.40	0.19	0.13	—	—	200	—	—	—	94.0
241	37	—	31	4	0.38	0.64	0.14	0.30	2.08	0.19	0.13	—	11	—	179	192	—	—	76.0
242	29	26	28	3	0.66	—	0.14	0.34	1.68	0.18	—	—	35	—	200	89	—	67	50.0
243	32	29	31	4	0.53	—	0.14	0.25	—	—	0.18	—	64	—	200	103	—	62	21.0
244	36	31	33	5	0.48	—	0.16	0.22	1.59	0.18	—	—	5	—	170	—	—	43	21.3
245	38	30	34	6	0.43	0.62	0.14	0.20	1.64	0.18	—	—	5	—	157	—	—	54	—
246	—	—	—	—	0.54	—	—	0.29	—	—	—	—	—	—	—	—	—	—	—
247	50	—	—	11	0.43	—	0.20	0.60	3.63	—	—	—	33	—	4600	51	—	—	—
248	—	—	—	—	1.91	—	0.28	0.22	1.99	0.07	0.25	0.21	—	—	400	—	—	—	—
249	36	—	24	9	1.70	—	0.51	0.27	1.92	0.07	0.25	0.11	9	—	228	29	—	—	75.2
250	—	—	—	—	0.06	—	—	0.33	0.40	—	0.17	—	7	—	44	45	—	25	—
251	34	—	—	10	0.59	0.65	0.22	0.26	2.99	1.05	0.43	—	21	—	118	43	—	29	—
252	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
253	33	—	—	8	1.18	—	0.25	0.32	2.32	0.52	0.15	0.36	10	0.49	420	73	—	—	184.2

TABLE 8 Composition of Some Beef Cattle Feeds—Continued

		Dry Basis (100% Dry Matter)											
Entry Number	Feed Name Description	International Feed Number*	Dry Matter (%)	DE (Mcal/kg)	ME (Mcal/kg)	NE _h (Mcal/kg)	NE _g (Mcal/kg)	TDN (%)	Crude Protein (%)	Ether Extract (%)	Ash (%)	Crude Fiber (%)	Cell Walls (%)
WHEAT <i>Triticum aestivum</i>													
254	bran	4-05-190	89	3.09	2.53	1.63	1.03	70	17.1	4.4	6.9	11.3	51
255	bread, dehydrated	4-07-944	95	3.79	3.11	2.12	1.45	86	13.0	2.4	2.4	0.3	—
256	flour by-product, less than 7% fiber (wheat shorts)	4-05-201	88	3.22	2.64	1.73	1.11	73	18.6	5.2	4.9	7.7	—
257	flour by-product, less than 9.5% fiber (wheat middlings)	4-05-205	89	3.04	2.50	1.60	1.00	69	18.4	4.9	5.2	8.2	—
258	fresh, early vegetative	2-05-176	22	3.22	2.64	1.73	1.11	73	28.6	4.4	13.3	17.4	52
259	grain	4-05-211	89	3.88	3.18	2.18	1.50	88	16.0	2.0	1.9	2.9	—
260	grain, hard red spring	4-05-258	88	3.92	3.22	2.21	1.52	89	17.2	2.0	1.8	2.9	—
261	grain, hard winter	4-05-266	88	3.88	3.18	2.18	1.50	88	14.4	1.8	1.9	2.8	—
262	grain, soft red winter	4-05-294	88	3.92	3.22	2.21	1.52	89	13.0	1.8	2.1	2.4	—
263	grain, soft white winter	4-05-337	89	3.92	3.22	2.21	1.52	89	11.3	1.9	1.8	2.6	14
264	grain, soft white winter, pacific coast	4-06-555	89	3.88	3.18	2.18	1.50	88	11.2	2.2	2.1	2.8	—
265	grain screenings	4-05-216	89	3.13	2.57	1.67	1.06	71	15.8	3.9	6.1	7.7	—
266	hay, sun-cured	1-05-172	88	2.56	2.10	1.24	0.68	58	8.5	2.2	7.1	28.1	66
267	mill run, less than 9.5% fiber	4-05-206	90	3.48	2.86	1.91	1.27	79	17.2	4.6	5.9	9.2	—
268	silage, full bloom	3-05-185	25	2.60	2.13	1.28	0.71	59	8.1	3.0	8.4	30.9	—
269	straw	1-05-175	89	1.81	1.48	0.64	0.11	41	3.6	1.8	7.8	41.6	70
WHEAT, DURUM <i>Triticum durum</i>													
270	grain	4-05-224	88	3.75	3.07	2.09	1.43	85	15.9	2.0	1.8	2.5	—
WHEATGRASS, CRESTED <i>Agropyron desertorum</i>													
271	fresh, early vegetative	2-05-420	28	3.31	2.71	1.79	1.16	75	21.5	2.2	10.0	22.2	—
272	fresh, full bloom	2-05-424	45	2.69	2.21	1.34	0.77	61	9.8	3.6	9.3	30.3	—
273	fresh, post ripe	2-05-426	80	2.16	1.77	0.93	0.39	49	3.1	1.9	4.1	40.3	—
274	hay, sun-cured	1-05-418	93	2.34	1.92	1.07	0.52	53	12.4	2.3	7.2	32.9	—
WHEY <i>Bovis laurus</i>													
275	dehydrated (cattle)	4-01-182	93	3.57	2.93	1.97	1.32	81	14.2	0.7	9.8	0.2	0
276	fresh (cattle)	4-06-134	7	4.14	3.40	2.35	1.65	94	13.0	4.3	8.7	—	—
277	low lactose, dehydrated (dried whey product) (cattle)	4-01-186	93	3.48	2.86	1.91	1.27	79	17.9	1.1	16.5	0.2	—
WINTERFAT, COMMON <i>Eurotia lanata</i>													
278	fresh, stem-cured	2-26-142	80	1.54	1.27	0.41	—	35	10.8	2.8	15.8	—	72
YEAST, BREWERS <i>Saccharomyces cerevisiae</i>													
279	dehydrated	7-05-527	93	3.48	2.86	1.91	1.27	79	46.9	0.9	7.1	3.1	—
YEAST, IRRADIATED <i>Saccharomyces cerevisiae</i>													
280	dehydrated	7-05-529	94	3.35	2.75	1.82	1.19	76	51.2	1.2	6.6	6.6	—
YEAST, PRIMARY <i>Saccharomyces cerevisiae</i>													
281	dehydrated	7-05-533	93	3.40	2.78	1.85	1.22	77	51.8	1.1	8.6	3.3	—
YEAST, TORULA <i>Torulispora utilis</i>													
282	dehydrated	7-05-534	93	3.44	2.82	1.86	1.24	78	52.7	1.7	8.3	2.4	—

Entry Number	Acid Detergent Fiber (%)	Hemi-cellulose (%)	Cellulose (%)	Lignin (%)	Calcium (%)	Chlorine (%)	Magnesium (%)	Phosphorus (%)	Potassium (%)	Sodium (%)	Sulfur (%)	Cobalt (mg/kg)	Copper (mg/kg)	Iodine (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Selenium (mg/kg)	Zinc (mg/kg)	Carotene (Provitamin A) Vitamin A Activity (1000 IU/kg)
254	15	34	11	3	0.13	0.05	0.60	1.38	1.56	0.04	0.25	0.11	14	0.07	128	125	0.43	128	1.2
255	—	—	—	—	0.07	—	—	0.11	—	—	—	—	—	—	—	—	—	—	—
256	—	—	—	—	0.10	0.08	0.28	0.91	1.06	0.03	0.22	0.12	13	—	82	132	0.49	124	—
257	—	—	—	—	0.13	0.04	0.40	0.99	1.13	0.19	0.20	0.10	22	0.12	93	126	0.83	116	1.4
258	30	18	24	4	0.42	—	0.21	0.40	3.50	0.18	0.22	—	—	—	100	—	—	—	208.0
259	8	—	8	—	0.04	0.08	0.16	0.42	0.42	0.05	0.18	0.14	7	0.10	61	42	0.30	50	0.0
260	13	—	8	—	0.04	0.09	0.17	0.43	0.41	0.03	0.17	0.13	7	—	64	42	0.29	52	0.0
261	4	—	—	—	0.05	0.06	0.13	0.43	0.49	0.02	0.15	0.16	5	—	35	33	0.45	43	—
262	—	—	—	—	0.05	0.08	0.11	0.43	0.46	0.01	0.12	0.12	7	—	30	36	0.65	48	—
263	4	—	—	—	0.07	0.09	0.13	0.36	0.46	0.04	0.16	0.15	8	—	41	43	0.06	29	—
264	—	—	—	—	0.10	—	0.15	0.34	0.51	0.10	0.18	—	—	—	60	—	—	—	—
265	—	—	6	8	0.15	—	0.18	0.39	0.58	0.10	0.22	—	—	—	60	33	0.68	—	—
266	41	—	—	7	0.15	—	0.12	0.30	1.00	0.21	0.22	—	—	—	200	—	—	—	34.2
267	—	—	—	—	0.11	—	0.52	1.13	1.33	0.24	0.34	0.23	21	—	105	116	—	—	—
268	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
269	54	—	39	14	0.18	0.32	0.12	0.05	1.42	0.14	0.19	0.05	4	—	157	41	—	6	0.9
270	—	—	—	—	0.10	—	0.17	0.41	0.51	—	—	0.09	8	—	48	32	1.02	37	—
271	—	—	—	—	0.46	—	0.28	0.34	—	—	—	—	—	—	—	—	—	—	180.4
272	—	—	—	—	0.39	—	0.09	0.28	1.04	0.01	0.47	—	7	—	—	43	—	13	61.6
273	—	—	—	—	0.27	—	—	0.07	—	—	—	0.25	8	—	—	53	—	—	0.1
274	36	—	—	6	0.33	—	0.16	0.21	2.00	—	—	0.24	16	—	178	36	0.40	32	8.9
275	0	0	—	—	0.92	0.08	0.14	0.82	1.23	0.70	1.12	0.12	50	—	181	6	—	3	—
276	—	—	—	—	0.73	—	—	0.65	2.75	—	—	—	—	—	290	3	—	—	—
277	—	—	—	—	1.71	1.10	0.23	1.12	3.16	1.54	1.15	—	8	10.55	262	9	0.06	8	—
278	44	—	—	10	1.98	—	—	0.12	—	—	—	—	—	—	—	—	—	—	7.2
279	—	—	—	—	0.13	0.08	0.27	1.49	1.79	0.08	0.45	0.20	35	0.38	117	6	0.98	41	—
280	—	—	—	—	0.83	—	—	1.51	2.28	—	—	—	—	—	—	—	—	—	—
281	—	—	—	—	0.39	0.02	0.39	1.86	—	—	0.62	—	—	—	324	4	—	—	—
282	—	—	—	—	0.54	0.02	0.18	1.71	2.04	0.04	0.59	0.03	14	2.69	126	9	1.08	100	—

TABLE 9 Composition of Mineral Supplements for Beef Cattle^a

Entry Number	Feed Name Description	Dry Basis (100% Dry Matter)																
		International Feed Number (%)	Dry Matter (%)	Equivalent N x 6.25 (%)	Calcium (Ca) (%)	Chlorine (Cl) (%)	Magnesium (Mg) (%)	Phosphorus (P) (%)	Potassium (K) (%)	Sulfur (S) (%)	Cobalt (Co) (mg/kg)	Copper (Cu) (mg/kg)	Fluorine (F) (mg/kg)	Iodine (I) (mg/kg)	Iron (Fe) (mg/kg)	Manganese (Mn) (mg/kg)	Selenium (Se) (mg/kg)	Zinc (Zn) (mg/kg)
01	AMMONIUM phosphate, mono-basic, (NH ₄)H ₂ PO ₄	6-09-338	97	70.9	0.28	—	0.46	24.74	0.01	0.06	1.46	10	2500	—	17400	400	—	100
02	phosphate, dibasic, (NH ₄) ₂ HPO ₄	6-00-370	97	115.9	0.52	—	0.46	20.60	0.01	0.05	2.16	—	10	2100	—	12400	400	100
03	BONE sulfate	6-09-339	100	134.1	—	—	—	—	—	—	24.10	—	1	—	10	1	—	—
04	charcoal (Bone black) (Bone char)	6-00-402	90	9.4	30.11	—	0.59	14.14	0.16	—	—	—	—	—	—	—	—	—
05	meal, steamed	6-00-400	97	8.4	31.53	0.01	0.64	14.22	0.19	0.40	0.21	—	14	—	31	780	34	342
06	calcium carbonate, CaCO ₃	6-01-069	100	—	39.39	—	0.05	0.04	0.06	0.06	—	—	—	—	—	300	300	—
07	phosphate, mono-basic, from defluorinated phosphoric acid	6-01-082	97	—	16.40	—	0.61	21.60	0.08	0.06	1.22	10	10	2100	—	15800	360	90
08	phosphate, dibasic, from defluorinated phosphoric acid (Di-calcium phosphate)	6-01-080	97	—	22.00	—	0.59	19.30	0.07	0.05	1.14	10	10	1800	—	14400	300	100
09	sulfate, dihydrate (Gypsum), CaSO ₄ · 2H ₂ O	6-01-090	85	—	25.90	—	2.61	0.01	—	23.54	—	—	—	—	2010	—	—	—
10	COBALT carbonate, CaCO ₃	6-01-566	99 ^b	—	—	—	—	—	—	0.20	460000	—	—	—	500	—	—	—
11	COLLOIDAL clay (soft rock phosphate)	6-03-947	99 ^b	—	17.17	—	0.38	9.09	—	0.10	—	—	15000	—	19200	—	—	—
12	COPPER (CUPRIC) sulfate, pentahydrate, CuSO ₄ · 5H ₂ O, cp ^c	6-01-720	100	—	—	—	—	—	—	12.84	—	254500	—	—	—	—	—	—
13	CURACAO phosphate	6-05-586	99 ^b	—	34.34	—	0.81	14.14	—	0.20	—	—	5500	—	3500	—	—	—
14	ETHYLENEDIAMINE dihydrochloride	6-01-842	100 ^b	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[illegible]

^aThe composition of mineral ingredients that are hydrated (e.g., $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is shown, including the waters of hydration. Mineral compositions

of feed grade mineral supplements vary by source, mining site,

^bDry matter values have

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Appendix

Tables 10 and 11

TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupois system)^{a,b,c}

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	TDN (%)	Ca (%)	P (%)
<i>Medium-frame steer calves</i>										
300	0.5	7.8	0.75	9.6	0.89	0.50	0.25	54.0	0.31	0.20
	1.0	8.4	0.95	11.4	0.96	0.57	0.31	58.5	0.45	0.24
	1.5	8.7	1.14	13.2	1.04	0.64	0.38	63.0	0.58	0.28
	2.0	8.9	1.32	14.8	1.11	0.70	0.44	67.5	0.72	0.32
	2.5	8.9	1.48	16.7	1.21	0.79	0.51	73.5	0.87	0.37
	3.0	8.0	1.60	19.9	1.39	0.95	0.64	85.0	1.13	0.47
400	0.5	9.7	0.87	8.9	0.89	0.50	0.25	54.0	0.27	0.18
	1.0	10.4	1.06	10.3	0.96	0.57	0.31	58.5	0.38	0.21
	1.5	10.8	1.24	11.5	1.04	0.64	0.38	63.0	0.47	0.25
	2.0	11.0	1.41	12.7	1.11	0.70	0.44	67.5	0.56	0.26
	2.5	11.0	1.56	14.2	1.21	0.79	0.51	73.5	0.68	0.30
	3.0	10.0	1.65	16.6	1.39	0.95	0.64	85.0	0.86	0.37
500	0.5	11.5	0.98	8.5	0.89	0.50	0.25	54.0	0.25	0.17
	1.0	12.3	1.16	9.5	0.96	0.57	0.31	58.5	0.32	0.20
	1.5	12.8	1.33	10.5	1.04	0.64	0.38	63.0	0.40	0.22
	2.0	13.1	1.49	11.4	1.11	0.70	0.44	67.5	0.47	0.24
	2.5	13.0	1.63	12.5	1.21	0.79	0.51	73.5	0.56	0.27
	3.0	11.8	1.69	14.4	1.39	0.95	0.64	85.0	0.69	0.32
600	0.5	13.2	1.08	8.2	0.89	0.50	0.25	54.0	0.23	0.18
	1.0	14.1	1.26	9.0	0.96	0.57	0.31	58.5	0.28	0.19
	1.5	14.7	1.42	9.8	1.04	0.64	0.38	63.0	0.35	0.21
	2.0	15.0	1.57	10.5	1.11	0.70	0.44	67.5	0.40	0.22
	2.5	14.9	1.69	11.4	1.21	0.79	0.51	73.5	0.46	0.24
	3.0	13.5	1.73	12.9	1.39	0.95	0.64	85.0	0.57	0.29
700	0.5	14.8	1.18	7.9	0.89	0.50	0.25	54.0	0.22	0.18
	1.0	15.8	1.35	8.6	0.96	0.57	0.31	58.5	0.27	0.18
	1.5	16.3	1.50	9.2	1.04	0.64	0.38	63.0	0.31	0.20
	2.0	16.8	1.65	9.8	1.11	0.70	0.44	67.5	0.34	0.21
	2.5	16.7	1.75	10.5	1.21	0.79	0.51	73.5	0.40	0.22
	3.0	15.2	1.77	11.7	1.39	0.95	0.64	85.0	0.49	0.26

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TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupois system)^{a,b,c}—Continued

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	TDN (%)	Ca (%)	P (%)
800	0.5	16.4	1.27	7.7	0.89	0.50	0.25	54.0	0.22	0.17
	1.0	17.5	1.44	8.3	0.96	0.57	0.31	58.5	0.24	0.19
	1.5	18.2	1.58	8.8	1.04	0.64	0.38	63.0	0.28	0.19
	2.0	18.6	1.72	9.2	1.11	0.70	0.44	67.5	0.31	0.20
	2.5	18.5	1.81	9.8	1.21	0.79	0.51	73.5	0.35	0.21
	3.0	16.8	1.81	10.8	1.39	0.95	0.64	85.0	0.42	0.25
900	0.5	17.9	1.36	7.6	0.89	0.50	0.25	54.0	0.21	0.18
	1.0	19.1	1.52	8.0	0.96	0.57	0.31	58.5	0.23	0.18
	1.5	19.9	1.66	8.4	1.04	0.64	0.38	63.0	0.25	0.19
	2.0	20.3	1.79	8.8	1.11	0.70	0.44	67.5	0.28	0.20
	2.5	20.2	1.87	9.3	1.21	0.79	0.51	73.5	0.31	0.20
	3.0	18.3	1.85	10.1	1.39	0.95	0.64	85.0	0.37	0.23
1000	0.5	19.3	1.45	7.5	0.89	0.50	0.25	54.0	0.21	0.18
	1.0	20.7	1.60	7.8	0.96	0.57	0.31	58.5	0.21	0.18
	1.5	21.5	1.74	8.1	1.04	0.64	0.38	63.0	0.24	0.18
	2.0	22.0	1.85	8.4	1.11	0.70	0.44	67.5	0.25	0.19
	2.5	21.9	1.92	8.8	1.21	0.79	0.51	73.5	0.27	0.19
	3.0	19.8	1.88	9.5	1.39	0.95	0.64	85.0	0.32	0.22
<i>Large-frame steer calves and compensating medium-frame yearling steers</i>										
300	0.5	8.2	0.77	9.5	0.86	0.48	0.23	52.5	0.30	0.19
	1.0	8.7	0.99	11.3	0.92	0.54	0.26	56.0	0.46	0.23
	1.5	9.1	1.19	12.9	0.98	0.59	0.33	59.5	0.58	0.27
	2.0	9.4	1.37	14.6	1.04	0.64	0.38	63.5	0.70	0.30
	2.5	9.6	1.55	16.3	1.11	0.70	0.44	67.5	0.85	0.34
	3.0	9.6	1.73	18.0	1.18	0.77	0.49	72.0	0.99	0.39
400	3.5	9.3	1.88	20.3	1.29	0.86	0.57	78.5	1.16	0.45
	0.5	10.1	0.89	8.9	0.86	0.48	0.23	52.5	0.26	0.17
	1.0	10.8	1.10	10.2	0.92	0.54	0.26	56.0	0.37	0.20
	1.5	11.3	1.30	11.4	0.98	0.59	0.33	59.5	0.47	0.23
	2.0	11.7	1.47	12.7	1.04	0.64	0.38	63.5	0.57	0.26
	2.5	11.9	1.64	13.9	1.11	0.70	0.44	67.5	0.65	0.30
500	3.0	11.9	1.81	15.2	1.18	0.77	0.49	72.0	0.76	0.33
	3.5	11.5	1.94	16.9	1.29	0.86	0.57	78.5	0.90	0.36
	0.5	12.0	1.0	8.5	0.86	0.48	0.23	52.5	0.24	0.17
	1.0	12.8	1.21	9.5	0.92	0.54	0.26	56.0	0.33	0.19
	1.5	13.4	1.40	10.4	0.98	0.59	0.33	59.5	0.39	0.21
	2.0	13.8	1.57	11.4	1.04	0.64	0.38	63.5	0.46	0.24
600	2.5	14.0	1.73	12.4	1.11	0.70	0.44	67.5	0.55	0.25
	3.0	14.0	1.88	13.4	1.18	0.77	0.49	72.0	0.63	0.28
	3.5	13.6	2.00	14.7	1.29	0.86	0.57	78.5	0.73	0.32
	0.5	13.8	1.11	8.2	0.86	0.48	0.23	52.5	0.22	0.18
	1.0	14.6	1.31	9.0	0.92	0.54	0.26	56.0	0.29	0.18
	1.5	15.3	1.50	9.7	0.98	0.59	0.33	59.5	0.35	0.20
700	2.0	15.8	1.66	10.5	1.04	0.64	0.38	63.5	0.40	0.22
	2.5	16.1	1.81	11.3	1.11	0.70	0.44	67.5	0.47	0.23
	3.0	16.1	1.95	12.1	1.18	0.77	0.49	72.0	0.52	0.26
	3.5	15.6	2.05	13.2	1.29	0.86	0.57	78.5	0.61	0.28
	0.5	15.4	1.21	7.9	0.86	0.48	0.23	52.5	0.21	0.17
	1.0	16.4	1.41	8.6	0.92	0.54	0.26	56.0	0.27	0.19
800	1.5	17.2	1.59	9.2	0.98	0.59	0.33	59.5	0.31	0.19
	2.0	17.8	1.74	9.8	1.04	0.64	0.38	63.5	0.36	0.21
	2.5	18.0	1.88	10.5	1.11	0.70	0.44	67.5	0.40	0.22
	3.0	18.0	2.01	11.1	1.18	0.77	0.49	72.0	0.45	0.23
	3.5	17.5	2.10	12.0	1.29	0.86	0.57	78.5	0.52	0.26

TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupolis system)^{a,b,c}—Continued

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	TDN (%)	Ca (%)	P (%)
800	0.5	17.1	1.31	7.7	0.86	0.48	0.23	52.5	0.21	0.18
	1.0	18.2	1.51	8.3	0.92	0.54	0.28	56.0	0.24	0.18
	1.5	19.0	1.68	8.8	0.98	0.59	0.33	59.5	0.28	0.19
	2.0	19.6	1.82	9.3	1.04	0.64	0.38	63.5	0.32	0.20
	2.5	19.9	1.96	9.8	1.11	0.70	0.44	67.5	0.35	0.21
	3.0	19.9	2.07	10.4	1.18	0.77	0.49	72.0	0.40	0.22
	3.5	19.3	2.15	11.1	1.29	0.86	0.57	78.5	0.45	0.24
900	0.5	18.6	1.40	7.6	0.86	0.48	0.23	52.5	0.20	0.18
	1.0	19.8	1.60	8.0	0.92	0.54	0.28	56.0	0.23	0.18
	1.5	20.8	1.77	8.5	0.98	0.59	0.33	59.5	0.27	0.18
	2.0	21.4	1.90	8.9	1.04	0.64	0.38	63.5	0.29	0.20
	2.5	21.8	2.03	9.3	1.11	0.70	0.44	67.5	0.31	0.20
	3.0	21.7	2.13	9.8	1.18	0.77	0.49	72.0	0.36	0.21
	3.5	21.1	2.19	10.4	1.29	0.86	0.57	78.5	0.40	0.23
1000	0.5	20.2	1.49	7.5	0.86	0.48	0.23	52.5	0.20	0.17
	1.0	21.5	1.69	7.8	0.92	0.54	0.28	56.0	0.23	0.17
	1.5	22.5	1.85	8.2	0.98	0.59	0.33	59.5	0.25	0.18
	2.0	23.2	1.98	8.6	1.04	0.64	0.38	63.5	0.27	0.18
	2.5	23.6	2.09	8.9	1.11	0.70	0.44	67.5	0.29	0.19
	3.0	23.6	2.19	9.3	1.18	0.77	0.49	72.0	0.32	0.20
	3.5	22.8	2.24	9.8	1.29	0.86	0.57	78.5	0.35	0.21
1100	0.5	21.7	1.58	7.4	0.86	0.48	0.23	52.5	0.19	0.18
	1.0	23.1	1.77	7.7	0.92	0.54	0.28	56.0	0.21	0.18
	1.5	24.1	1.93	8.0	0.98	0.59	0.33	59.5	0.23	0.18
	2.0	24.9	2.05	8.3	1.04	0.64	0.38	63.5	0.25	0.18
	2.5	25.3	2.16	8.5	1.11	0.70	0.44	67.5	0.26	0.18
	3.0	25.3	2.25	8.9	1.18	0.77	0.49	72.0	0.29	0.19
	3.5	24.5	2.28	9.3	1.29	0.86	0.57	78.5	0.32	0.21
<i>Medium-frame bulls</i>										
300	0.5	7.8	0.76	9.7	0.88	0.49	0.24	53.5	0.31	0.20
	1.0	8.3	0.96	11.6	0.94	0.56	0.30	57.5	0.48	0.24
	1.5	8.6	1.15	13.4	1.01	0.62	0.35	61.5	0.62	0.28
	2.0	8.8	1.34	15.2	1.08	0.68	0.41	65.5	0.75	0.33
	2.5	8.9	1.52	17.0	1.15	0.74	0.47	70.0	0.92	0.37
	3.0	8.7	1.68	19.3	1.26	0.84	0.54	76.5	1.09	0.43
400	0.5	9.6	0.87	9.0	0.88	0.49	0.24	53.5	0.28	0.18
	1.0	10.3	1.07	10.4	0.94	0.56	0.30	57.5	0.39	0.21
	1.5	10.7	1.26	11.8	1.01	0.62	0.35	61.5	0.49	0.25
	2.0	11.0	1.44	13.1	1.08	0.68	0.41	65.5	0.60	0.28
	2.5	11.1	1.60	14.4	1.15	0.74	0.47	70.0	0.70	0.32
	3.0	10.8	1.74	16.1	1.26	0.84	0.54	76.5	0.84	0.37
500	0.5	11.4	0.98	8.6	0.88	0.49	0.24	53.5	0.25	0.17
	1.0	12.1	1.17	9.7	0.94	0.56	0.30	57.5	0.35	0.20
	1.5	12.7	1.35	10.7	1.01	0.62	0.35	61.5	0.42	0.23
	2.0	13.0	1.52	11.7	1.08	0.68	0.41	65.5	0.49	0.25
	2.5	13.1	1.68	12.8	1.15	0.74	0.47	70.0	0.59	0.27
	3.0	12.8	1.81	14.1	1.26	0.84	0.54	76.5	0.69	0.31
600	0.5	13.1	1.08	8.3	0.88	0.49	0.24	53.5	0.24	0.19
	1.0	13.9	1.27	9.2	0.94	0.56	0.30	57.5	0.30	0.19
	1.5	14.5	1.44	10.0	1.01	0.62	0.35	61.5	0.36	0.21
	2.0	14.9	1.61	10.8	1.08	0.68	0.41	65.5	0.43	0.24
	2.5	15.0	1.75	11.6	1.15	0.74	0.47	70.0	0.50	0.25
	3.0	14.7	1.86	12.7	1.26	0.84	0.54	76.5	0.57	0.29

80 Nutrient Requirements of Beef Cattle

TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupois system)^{a,b,c}—Continued

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	TDN (%)	Ca (%)	P (%)
700	0.5	14.7	1.18	8.0	0.88	0.49	0.24	53.5	0.23	0.18
	1.0	15.6	1.37	8.8	0.94	0.56	0.30	57.5	0.28	0.20
	1.5	16.3	1.53	9.4	1.01	0.62	0.35	61.5	0.32	0.20
	2.0	16.7	1.69	10.1	1.08	0.68	0.41	65.5	0.38	0.22
	2.5	16.8	1.82	10.8	1.15	0.74	0.47	70.0	0.43	0.24
	3.0	16.5	1.92	11.7	1.26	0.84	0.54	76.5	0.49	0.25
800	0.5	16.2	1.27	7.8	0.88	0.49	0.24	53.5	0.22	0.19
	1.0	17.3	1.45	8.4	0.94	0.56	0.30	57.5	0.25	0.19
	1.5	18.0	1.61	9.0	1.01	0.62	0.35	61.5	0.29	0.20
	2.0	18.5	1.76	9.5	1.08	0.68	0.41	65.5	0.33	0.21
	2.5	18.6	1.89	10.1	1.15	0.74	0.47	70.0	0.38	0.23
	3.0	18.2	1.97	10.8	1.26	0.84	0.54	76.5	0.44	0.24
900	0.5	17.7	1.36	7.7	0.88	0.49	0.24	53.5	0.21	0.19
	1.0	18.9	1.54	8.2	0.94	0.56	0.30	57.5	0.25	0.19
	1.5	19.7	1.69	8.6	1.01	0.62	0.35	61.5	0.28	0.19
	2.0	20.2	1.83	9.1	1.08	0.68	0.41	65.5	0.31	0.21
	2.5	20.3	1.95	9.6	1.15	0.74	0.47	70.0	0.34	0.22
	3.0	19.9	2.02	10.2	1.26	0.84	0.54	76.5	0.39	0.23
1000	0.5	19.2	1.45	7.5	0.88	0.49	0.24	53.5	0.21	0.18
	1.0	20.4	1.62	8.0	0.94	0.56	0.30	57.5	0.24	0.18
	1.5	21.3	1.77	8.4	1.01	0.62	0.35	61.5	0.26	0.19
	2.0	21.8	1.90	8.7	1.08	0.68	0.41	65.5	0.28	0.19
	2.5	22.0	2.01	9.1	1.15	0.74	0.47	70.0	0.31	0.20
	3.0	21.5	2.07	9.6	1.26	0.84	0.54	76.5	0.35	0.22
1100	0.5	20.6	1.54	7.4	0.88	0.49	0.24	53.5	0.20	0.19
	1.0	21.9	1.70	7.8	0.94	0.56	0.30	57.5	0.22	0.19
	1.5	22.9	1.85	8.1	1.01	0.62	0.35	61.5	0.24	0.19
	2.0	23.4	1.97	8.4	1.08	0.68	0.41	65.5	0.26	0.19
	2.5	23.6	2.07	8.7	1.15	0.74	0.47	70.0	0.28	0.20
	3.0	23.1	2.11	9.2	1.26	0.84	0.54	76.5	0.32	0.21
<i>Large-frame bull calves and compensating large-frame yearling steers</i>										
300	0.5	7.9	0.77	9.7	0.86	0.48	0.23	52.5	0.31	0.20
	1.0	8.4	0.98	11.7	0.92	0.54	0.28	56.0	0.47	0.24
	1.5	8.8	1.18	13.5	0.98	0.59	0.33	59.5	0.63	0.28
	2.0	9.0	1.38	15.1	1.03	0.63	0.37	62.5	0.76	0.32
	2.5	9.2	1.56	17.0	1.09	0.69	0.42	66.5	0.91	0.36
	3.0	9.2	1.74	18.8	1.16	0.75	0.47	70.5	1.08	0.43
	3.5	9.1	1.91	20.9	1.24	0.82	0.53	75.5	1.24	0.48
	4.0	8.2	2.04	24.7	1.41	0.96	0.66	86.0	1.53	0.59
400	0.5	9.8	0.89	9.0	0.86	0.48	0.23	52.5	0.27	0.18
	1.0	10.4	1.09	10.5	0.92	0.54	0.28	56.0	0.40	0.21
	1.5	10.9	1.29	11.9	0.98	0.59	0.33	59.5	0.51	0.24
	2.0	11.2	1.48	13.1	1.03	0.63	0.37	62.5	0.61	0.28
	2.5	11.4	1.65	14.5	1.09	0.69	0.42	66.5	0.72	0.31
	3.0	11.5	1.82	15.9	1.16	0.75	0.47	70.5	0.82	0.35
	3.5	11.3	1.98	17.5	1.24	0.82	0.53	75.5	0.96	0.39
	4.0	10.2	2.08	20.3	1.41	0.96	0.66	86.0	1.19	0.48
500	0.5	11.6	1.00	8.6	0.86	0.48	0.23	52.5	0.25	0.19
	1.0	12.3	1.20	9.8	0.92	0.54	0.28	56.0	0.36	0.21
	1.5	12.9	1.39	10.9	0.98	0.59	0.33	59.5	0.43	0.22
	2.0	13.2	1.58	11.8	1.03	0.63	0.37	62.5	0.52	0.25

TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupois system)^{a,b,c}—Continued

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	TDN (%)	Ca (%)	P (%)
600	2.5	13.5	1.74	12.9	1.09	0.69	0.42	66.5	0.59	0.28
	3.0	13.6	1.90	14.0	1.16	0.75	0.47	70.5	0.68	0.31
	3.5	13.4	2.05	15.3	1.24	0.82	0.53	75.5	0.77	0.35
	4.0	12.0	2.13	17.5	1.41	0.96	0.66	86.0	0.97	0.40
	0.5	13.3	1.10	8.3	0.86	0.48	0.23	52.5	0.23	0.18
	1.0	14.1	1.30	9.2	0.92	0.54	0.28	56.0	0.31	0.20
	1.5	14.8	1.48	10.1	0.98	0.59	0.33	59.5	0.37	0.21
	2.0	15.2	1.67	10.9	1.03	0.63	0.37	62.5	0.44	0.23
	2.5	15.5	1.82	11.8	1.09	0.69	0.42	66.5	0.51	0.26
	3.0	15.3	1.97	12.7	1.16	0.75	0.47	70.5	0.58	0.27
	3.5	15.3	2.11	13.7	1.24	0.82	0.53	75.5	0.66	0.30
	4.0	13.8	2.16	15.6	1.41	0.96	0.66	86.0	0.81	0.37
	0.5	14.9	1.20	8.0	0.86	0.48	0.23	52.5	0.22	0.18
	1.0	15.9	1.40	8.8	0.92	0.54	0.28	56.0	0.29	0.19
	1.5	16.6	1.57	9.6	0.98	0.59	0.33	59.5	0.35	0.21
	2.0	17.0	1.75	10.2	1.03	0.63	0.37	62.5	0.39	0.22
700	2.5	17.4	1.90	11.0	1.09	0.69	0.42	66.5	0.44	0.24
	3.0	17.5	2.04	11.7	1.16	0.75	0.47	70.5	0.50	0.25
	3.5	17.2	2.16	12.5	1.24	0.82	0.53	75.5	0.56	0.28
	4.0	15.5	2.20	14.1	1.41	0.96	0.66	86.0	0.70	0.33
	0.5	16.5	1.30	7.9	0.86	0.48	0.23	52.5	0.21	0.19
	1.0	17.5	1.49	8.5	0.92	0.54	0.28	56.0	0.26	0.19
	1.5	18.3	1.66	9.1	0.98	0.59	0.33	59.5	0.31	0.20
	2.0	18.8	1.84	9.7	1.03	0.63	0.37	62.5	0.35	0.21
	2.5	19.2	1.97	10.3	1.09	0.69	0.42	66.5	0.40	0.23
	3.0	19.3	2.11	10.9	1.16	0.75	0.47	70.5	0.45	0.24
	3.5	19.0	2.22	11.6	1.24	0.82	0.53	75.5	0.50	0.26
	4.0	17.1	2.24	13.0	1.41	0.96	0.66	86.0	0.61	0.31
	0.5	18.0	1.39	7.7	0.86	0.48	0.23	52.5	0.22	0.18
	1.0	19.2	1.58	8.3	0.92	0.54	0.28	56.0	0.25	0.18
	1.5	20.0	1.74	8.8	0.98	0.59	0.33	59.5	0.29	0.20
	2.0	20.6	1.92	9.2	1.03	0.63	0.37	62.5	0.32	0.20
800	2.5	21.0	2.04	9.8	1.09	0.69	0.42	66.5	0.36	0.21
	3.0	21.1	2.17	10.3	1.16	0.75	0.47	70.5	0.40	0.23
	3.5	20.8	2.27	10.9	1.24	0.82	0.53	75.5	0.45	0.24
	4.0	18.7	2.27	12.1	1.41	0.96	0.66	86.0	0.53	0.28
	0.5	19.5	1.48	7.6	0.86	0.48	0.23	52.5	0.21	0.18
	1.0	20.7	1.66	8.1	0.92	0.54	0.28	56.0	0.25	0.19
	1.5	21.7	1.83	8.5	0.98	0.59	0.33	59.5	0.27	0.19
	2.0	22.3	1.99	8.9	1.03	0.63	0.37	62.5	0.30	0.20
	2.5	22.7	2.11	9.3	1.09	0.69	0.42	66.5	0.33	0.20
	3.0	22.8	2.23	9.7	1.16	0.75	0.47	70.5	0.36	0.21
	3.5	22.5	2.32	10.3	1.24	0.82	0.53	75.5	0.40	0.24
	4.0	20.2	2.30	11.3	1.41	0.96	0.66	86.0	0.48	0.27
	0.5	20.9	1.57	7.5	0.86	0.48	0.23	52.5	0.21	0.19
	1.0	22.3	1.75	7.9	0.92	0.54	0.28	56.0	0.23	0.19
	1.5	23.3	1.91	8.3	0.98	0.59	0.33	59.5	0.26	0.19
	2.0	23.9	2.07	8.6	1.03	0.63	0.37	62.5	0.28	0.19
1100	2.5	24.2	2.18	9.0	1.09	0.69	0.42	66.5	0.30	0.20
	3.0	24.5	2.29	9.3	1.16	0.75	0.47	70.5	0.32	0.21
	3.5	24.1	2.37	9.8	1.24	0.82	0.53	75.5	0.36	0.22
	4.0	21.7	2.33	10.7	1.41	0.96	0.66	86.0	0.43	0.25

82 Nutrient Requirements of Beef Cattle

TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupois system)^{a,b,c}—Continued

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _L (Mcal/lb)	TDN (%)	Ca (%)	P (%)
<i>Medium-frame heifer calves</i>										
300	0.5	7.5	0.73	9.6	0.92	0.54	0.28	56.0	0.29	0.21
	1.0	8.0	0.91	11.4	1.02	0.63	0.36	62.0	0.44	0.22
	1.5	8.2	1.08	13.1	1.13	0.72	0.44	68.5	0.59	0.27
	2.0	8.0	1.22	15.1	1.26	0.84	0.55	77.0	0.74	0.33
400	0.5	9.3	0.84	8.9	0.92	0.54	0.28	56.0	0.26	0.19
	1.0	9.9	1.01	10.2	1.02	0.63	0.36	62.0	0.36	0.20
	1.5	10.2	1.17	11.4	1.13	0.72	0.44	68.5	0.45	0.24
	2.0	10.0	1.29	12.9	1.26	0.84	0.55	77.0	0.57	0.29
500	0.5	11.0	0.94	8.5	0.92	0.54	0.28	56.0	0.24	0.18
	1.0	11.8	1.11	9.4	1.02	0.63	0.36	62.0	0.30	0.21
	1.5	12.1	1.25	10.3	1.13	0.72	0.44	68.5	0.38	0.22
	2.0	11.8	1.35	11.4	1.26	0.84	0.55	77.0	0.45	0.24
600	0.5	12.6	1.04	8.1	0.92	0.54	0.28	56.0	0.23	0.18
	1.0	13.5	1.19	8.8	1.02	0.63	0.36	62.0	0.28	0.20
	1.5	13.8	1.32	9.5	1.13	0.72	0.44	68.5	0.32	0.21
	2.0	13.5	1.41	10.4	1.26	0.84	0.55	77.0	0.38	0.23
700	0.5	14.1	1.13	7.9	0.92	0.54	0.28	56.0	0.22	0.19
	1.0	15.1	1.28	8.4	1.02	0.63	0.36	62.0	0.25	0.19
	1.5	15.5	1.39	9.0	1.13	0.72	0.44	68.5	0.28	0.20
	2.0	15.2	1.46	9.6	1.26	0.84	0.55	77.0	0.32	0.22
800	0.5	15.6	1.22	7.7	0.92	0.54	0.28	56.0	0.21	0.18
	1.0	16.7	1.36	8.1	1.02	0.63	0.36	62.0	0.22	0.18
	1.5	17.2	1.46	8.5	1.13	0.72	0.44	68.5	0.24	0.19
	2.0	16.8	1.51	9.0	1.26	0.84	0.55	77.0	0.28	0.20
900	0.5	17.1	1.31	7.5	0.92	0.54	0.28	56.0	0.21	0.18
	1.0	18.3	1.44	7.8	1.02	0.63	0.36	62.0	0.22	0.18
	1.5	18.8	1.53	8.1	1.13	0.72	0.44	68.5	0.22	0.19
	2.0	18.3	1.56	8.5	1.26	0.84	0.55	77.0	0.25	0.19
1000	0.5	18.5	1.39	7.4	0.92	0.54	0.28	56.0	0.20	0.19
	1.0	19.8	1.51	7.6	1.02	0.63	0.36	62.0	0.20	0.18
	1.5	20.3	1.59	7.8	1.13	0.72	0.44	68.5	0.21	0.18
	2.0	19.8	1.61	8.1	1.26	0.84	0.55	77.0	0.22	0.19
<i>Large-frame heifer calves and compensating medium-frame yearling heifers</i>										
300	0.5	7.8	0.76	9.5	0.89	0.50	0.25	54.0	0.31	0.20
	1.0	8.4	0.95	11.3	0.98	0.58	0.32	59.0	0.45	0.24
	1.5	8.8	1.13	13.0	1.05	0.65	0.39	64.0	0.58	0.25
	2.0	8.9	1.30	14.6	1.14	0.74	0.46	69.5	0.69	0.30
	2.5	8.7	1.45	16.7	1.26	0.84	0.55	77.0	0.86	0.35
400	0.5	9.7	0.87	8.9	0.89	0.50	0.25	54.0	0.27	0.18
	1.0	10.5	1.06	10.1	0.98	0.58	0.32	59.0	0.36	0.21
	1.5	10.9	1.23	11.3	1.05	0.65	0.39	64.0	0.45	0.22
	2.0	11.1	1.38	12.6	1.14	0.74	0.46	69.5	0.54	0.26
	2.5	10.8	1.51	14.1	1.26	0.84	0.55	77.0	0.65	0.31
500	0.5	11.5	0.98	8.4	0.89	0.50	0.25	54.0	0.23	0.17
	1.0	12.4	1.16	9.4	0.98	0.58	0.32	59.0	0.30	0.20
	1.5	12.9	1.32	10.3	1.05	0.65	0.39	64.0	0.38	0.20
	2.0	13.1	1.46	11.2	1.14	0.74	0.46	69.5	0.44	0.24
	2.5	12.8	1.57	12.4	1.26	0.84	0.55	77.0	0.53	0.26
600	0.5	13.2	1.08	8.1	0.89	0.50	0.25	54.0	0.22	0.18
	1.0	14.1	1.25	8.9	0.98	0.58	0.32	59.0	0.28	0.19

TABLE 10 Nutrient Requirements for Growing and Finishing Cattle (Nutrient Concentration in Diet Dry Matter, avoidupois system)^{a,b,c}—Continued

Weight (lb)	Daily Gain (lb)	Dry Matter Intake (lb)	Protein Intake (lb)	Protein (%)	ME (Mcal/lb)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	TDN (%)	Ca (%)	P (%)
700	1.5	14.8	1.41	9.6	1.05	0.65	0.39	64.0	0.33	0.19
	2.0	15.0	1.54	10.3	1.14	0.74	0.46	69.5	0.38	0.22
	2.5	14.6	1.63	11.2	1.26	0.84	0.55	77.0	0.44	0.24
	0.5	14.8	1.18	7.9	0.89	0.50	0.25	54.0	0.21	0.18
	1.0	15.9	1.34	8.5	0.98	0.58	0.32	59.0	0.25	0.18
	1.5	16.6	1.49	9.0	1.05	0.65	0.39	64.0	0.29	0.19
	2.0	16.8	1.61	9.6	1.14	0.74	0.46	69.5	0.33	0.20
800	2.5	16.4	1.68	10.3	1.26	0.84	0.55	77.0	0.38	0.22
	0.5	16.4	1.27	7.7	0.89	0.50	0.25	54.0	0.20	0.17
	1.0	17.6	1.43	8.2	0.98	0.58	0.32	59.0	0.24	0.18
	1.5	18.3	1.57	8.6	1.05	0.65	0.39	64.0	0.25	0.18
	2.0	18.6	1.67	9.0	1.14	0.74	0.46	69.5	0.28	0.19
	2.5	18.1	1.74	9.6	1.26	0.84	0.55	77.0	0.33	0.21
	0.5	17.8	1.36	7.5	0.89	0.50	0.25	54.0	0.20	0.18
900	1.0	19.2	1.52	7.9	0.98	0.58	0.32	59.0	0.22	0.18
	1.5	20.0	1.64	8.2	1.05	0.65	0.39	64.0	0.23	0.18
	2.0	20.3	1.74	8.6	1.14	0.74	0.46	69.5	0.26	0.18
	2.5	19.8	1.78	9.0	1.26	0.84	0.55	77.0	0.29	0.20
	0.5	19.3	1.45	7.4	0.89	0.50	0.25	54.0	0.19	0.18
	1.0	20.8	1.60	7.7	0.98	0.58	0.32	59.0	0.21	0.18
	1.5	21.7	1.71	8.0	1.05	0.65	0.39	64.0	0.21	0.18
1000	2.0	22.0	1.80	8.2	1.14	0.74	0.46	69.5	0.23	0.18
	2.5	21.5	1.83	8.6	1.26	0.84	0.55	77.0	0.25	0.18
	0.5	20.8	1.54	7.3	0.89	0.50	0.25	54.0	0.19	0.18
	1.0	22.3	1.68	7.5	0.98	0.58	0.32	59.0	0.20	0.18
	1.5	23.3	1.78	7.7	1.05	0.65	0.39	64.0	0.20	0.18
	2.0	23.6	1.86	7.9	1.14	0.74	0.46	69.5	0.21	0.18
	2.5	23.1	1.88	8.2	1.26	0.84	0.55	77.0	0.22	0.18

^aShrink liveweight basis, see text.^bVitamin A requirements are 1000 IU¹ per pound of diet.^cThis table gives reasonable examples of nutrient concentrations that should be suitable to formulate diets for specific management goals. It does not imply that diets with other nutrient concentrations when consumed in sufficient amounts would be inadequate to meet nutrient requirements.

TABLE 11. Nutrient Requirements of Breeding Cattle (avoidpoups system)

Weight ^a (lb)	Gain ^b (lb)	Energy		In Diet DM										Total Protein		Calcium		Phosphorus		Vitamin A ^d	
		Daily		In Diet DM										Daily		Daily		Daily		Daily	
		ME (Mcal)	NE _m (Mcal)	ME (Mcal/lb)	NE _m (Mcal/lb)	TDN (lb)	NE _m (Mcal)	NE _g (Mcal)	ME (Mcal/lb)	TDN (%)	NE _m (Mcal/lb)	NE _g (Mcal/lb)	Daily (lb)	DM (%)	Daily (g)	DM (%)	Daily (g)	DM (%)	Daily (1000's IU)		
Pregnant yearling heifers—Last third of pregnancy																					
700	0.9	15.3	13.9	8.5	7.95	NA ^c	NA ^c	0.91	55.4	0.52	NA ^c	1.3	8.4	19	0.27	14	0.20	19			
700	1.4	15.8	15.7	9.6	7.95	0.87	0.87	0.99	60.3	0.40	0.34	1.4	9.0	24	0.33	15	0.21	20			
700	1.9	15.8	17.4	10.6	7.95	1.89	1.89	1.10	67.0	0.70	0.43	1.5	9.8	27	0.33	16	0.21	20			
750	0.9	16.1	14.6	8.9	8.25	NA	NA	0.90	55.1	0.52	NA	1.3	8.3	20	0.27	14	0.19	20			
750	1.4	16.6	16.4	10.0	8.25	0.92	0.92	0.96	59.0	0.60	0.33	1.5	8.9	24	0.32	16	0.21	21			
750	1.9	16.6	18.2	11.1	8.25	1.99	1.99	1.09	66.5	0.69	0.42	1.6	9.5	28	0.37	17	0.23	21			
800	0.9	16.8	15.2	9.2	8.56	NA	NA	0.90	54.8	0.51	NA	1.4	8.2	21	0.28	15	0.20	21			
800	1.4	17.4	17.1	10.4	8.56	0.96	0.96	0.98	59.6	0.59	0.33	1.5	8.8	25	0.33	16	0.21	22			
800	1.9	17.5	19.0	11.6	8.56	2.09	2.09	1.08	66.1	0.69	0.42	1.6	9.3	28	0.35	17	0.21	22			
850	0.9	17.6	15.7	9.6	8.85	NA	NA	0.89	54.5	0.51	NA	1.4	8.2	21	0.26	16	0.20	22			
850	1.4	18.2	17.8	10.8	8.85	1.01	0.97	0.97	59.3	0.39	0.32	1.6	8.6	25	0.30	17	0.21	23			
850	1.9	18.3	19.8	12.1	8.85	2.19	1.06	1.06	65.7	0.68	0.41	1.7	9.1	28	0.34	18	0.22	23			
900	0.9	18.3	16.3	9.9	9.15	NA	NA	0.89	54.3	0.51	NA	1.5	8.1	22	0.26	17	0.20	23			
900	1.4	19.0	18.5	11.3	9.15	1.05	0.97	0.97	59.1	0.38	0.32	1.6	8.5	26	0.30	18	0.21	24			
900	1.9	19.2	20.6	12.5	9.15	2.28	1.07	1.07	65.4	0.68	0.41	1.7	9.0	28	0.32	19	0.21	24			
950	0.9	19.0	16.9	10.3	9.44	NA	NA	0.89	54.1	0.50	NA	1.5	8.0	23	0.27	17	0.20	24			
950	1.4	19.8	19.1	11.7	9.44	1.09	0.97	0.97	58.9	0.58	0.32	1.7	8.4	26	0.29	19	0.21	25			
950	1.9	20.0	21.3	13.0	9.44	2.38	1.07	1.07	65.1	0.67	0.40	1.8	8.8	29	0.32	19	0.21	25			
Dry pregnant mature cows—Middle third of pregnancy																					
800	0.0	15.3	12.3	7.5	6.41	NA	NA	0.80	46.8	0.42	NA	1.1	7.1	12	0.17	12	0.17	19			
900	0.0	16.7	13.4	8.2	7.00	NA	NA	0.80	46.8	0.42	NA	1.2	7.0	14	0.18	14	0.18	21			
1000	0.0	18.1	14.5	8.8	7.57	NA	NA	0.80	48.8	0.42	NA	1.3	7.0	15	0.18	15	0.18	23			
1100	0.0	19.5	15.6	9.5	8.13	NA	NA	0.80	48.8	0.42	NA	1.4	7.0	17	0.19	17	0.19	25			
1200	0.0	20.8	16.6	10.1	8.68	NA	NA	0.80	48.8	0.42	NA	1.4	6.9	18	0.19	18	0.19	26			
1300	0.0	22.0	17.7	10.8	9.22	NA	NA	0.80	48.8	0.42	NA	1.5	6.9	20	0.20	20	0.20	28			
1400	0.0	23.3	18.7	11.4	9.75	NA	NA	0.80	48.8	0.42	NA	1.6	6.9	21	0.20	21	0.20	30			
Dry pregnant mature cows—Last third of pregnancy																					
800	0.9	16.8	15.0	9.2	8.56	NA	NA	0.89	54.5	0.51	NA	1.4	8.2	20	0.26	15	0.20	21			
900	0.9	18.2	16.2	9.8	9.15	NA	NA	0.89	54.0	0.50	NA	1.5	8.0	22	0.27	17	0.21	23			
1000	0.9	19.6	17.3	10.5	9.72	NA	NA	0.88	53.6	0.50	NA	1.6	7.9	23	0.26	18	0.20	25			
1100	0.9	21.0	18.3	11.2	10.28	NA	NA	0.87	53.2	0.49	NA	1.6	7.8	25	0.26	20	0.21	26			
1200	0.9	22.3	19.4	11.8	10.83	NA	NA	0.87	52.9	0.49	NA	1.7	7.8	26	0.26	21	0.21	28			
1300	0.9	23.6	20.4	12.5	11.37	NA	NA	0.87	52.7	0.48	NA	1.8	7.7	28	0.26	23	0.21	30			
1400	0.9	24.9	21.5	13.1	11.90	NA	NA	0.86	52.5	0.48	NA	1.9	7.6	29	0.26	24	0.21	32			
Two-year-old heifers nursing calves—First 2-4 months postpartum—10 lb milk/day																					
700	0.5	15.9	17.0	10.3	9.20	0.87	1.07	0.87	65.1	0.67	0.40	1.9 ^e	11.3	26	0.36	17	0.24	28			
750	0.5	16.7	17.7	10.8	9.51	0.92	1.06	0.92	64.4	0.66	0.39	1.9 ^e	11.0	26	0.34	18	0.24	30			
800	0.5	17.6	18.4	11.2	9.81	0.96	1.05	0.96	63.8	0.66	0.39	1.9 ^e	10.8	27	0.34	19	0.24	31			
850	0.5	18.4	19.1	11.6	10.11	1.01	1.04	1.01	63.2	0.65	0.38	1.9 ^e	10.6	27	0.33	19	0.23	33			
900	0.5	19.2	19.8	12.0	10.40	1.05	1.03	1.05	62.7	0.64	0.37	2.0 ^e	10.4	28	0.32	20	0.23	34			
950	0.5	20.0	20.5	12.5	10.69	1.09	1.02	1.09	62.3	0.63	0.37	2.0 ^e	10.2	28	0.31	21	0.23	35			
1000	0.5	20.8	21.1	12.9	10.98	1.14	1.02	1.02	61.9	0.62	0.36	2.1 ^e	10.0	29	0.31	22	0.23	37			

Cows nursing calves—Average milking ability—First 3–4 months postpartum—10 lb milk/day

800	0.0	17.3	16.6	10.1	9.81	NA	0.96	58.2	0.57	NA	1.9 ^a	10.2	23	0.30	17	0.22	31
900	0.0	18.8	17.7	10.8	10.40	NA	0.94	57.3	0.55	NA	1.9 ^a	9.9	24	0.28	19	0.22	33
1000	0.0	20.2	18.8	11.5	10.98	NA	0.93	56.6	0.55	NA	2.0 ^a	9.6	25	0.28	20	0.22	36
1100	0.0	21.6	19.9	12.1	11.54	NA	0.92	56.0	0.54	NA	2.0 ^a	9.4	27	0.27	22	0.22	38
1200	0.0	23.0	21.0	12.8	12.09	NA	0.91	55.5	0.53	NA	2.1 ^a	9.3	28	0.27	23	0.22	41
1300	0.0	24.3	22.0	13.4	12.63	NA	0.90	55.1	0.52	NA	2.2 ^a	9.1	30	0.27	25	0.22	43
1400	0.0	25.6	23.0	14.0	13.15	NA	0.90	54.7	0.51	NA	2.3 ^a	9.0	31	0.27	26	0.22	46

Cows nursing calves—Superior milking ability—First 3–4 months postpartum—20 lb milk/day

800	0.0	15.7	19.9	12.1	13.22	NA	1.27	77.3	0.85	NA	2.3 ^a	14.2	34	0.48	22	0.31	28
900	0.0	18.7	21.5	13.1	13.81	NA	1.15	69.8	0.74	NA	2.4 ^a	12.9	35	0.41	24	0.28	33
1000	0.0	20.6	22.7	13.8	14.38	NA	1.10	67.0	0.70	NA	2.5 ^a	12.3	36	0.39	25	0.27	37
1100	0.0	22.3	23.8	14.5	14.94	NA	1.07	65.2	0.67	NA	2.6 ^a	11.9	38	0.38	27	0.27	40
1200	0.0	23.8	24.9	15.2	15.49	NA	1.05	63.7	0.65	NA	2.7 ^a	11.5	39	0.36	28	0.26	42
1300	0.0	25.3	26.0	15.9	16.03	NA	1.03	62.6	0.64	NA	2.9 ^a	11.2	41	0.36	30	0.26	45
1400	0.0	26.7	27.1	16.5	16.56	NA	1.01	61.7	0.62	NA	2.9 ^a	11.0	42	0.35	31	0.26	47

Bulls, maintenance and slow rate of growth (regain body condition)
<1300 For growth and development use requirements for bulls in Tables 1, 2, 3, and 10.

1300	1.0	25.4	23.3	14.2	9.22	2.20	0.92	55.8	0.53	0.28	1.9	7.6	25	0.22	22	0.19	45
1300	1.5	26.1	25.5	15.6	9.22	3.43	0.96	59.7	0.59	0.33	2.0	7.9	28	0.24	23	0.19	46
1300	2.0	26.2	27.6	16.8	9.22	4.71	1.05	64.0	0.65	0.39	2.2	8.2	31	0.26	24	0.20	46
1400	1.0	26.8	24.6	15.0	9.75	2.33	0.92	55.8	0.53	0.28	2.0	7.5	26	0.21	23	0.19	48
1400	1.5	27.6	27.0	16.5	9.75	3.63	0.96	59.7	0.59	0.33	2.1	7.7	29	0.23	24	0.19	49
1400	2.0	27.7	29.1	17.8	9.75	4.98	1.05	64.0	0.65	0.39	2.2	8.0	31	0.25	25	0.20	49
1500	0.0	25.2	20.0	12.2	10.26	NA	0.79	46.4	0.41	NA	1.7	6.9	23	0.20	23	0.20	45
1500	1.0	26.3	25.9	15.8	10.26	2.45	0.92	55.8	0.53	0.28	2.1	7.4	27	0.21	24	0.19	50
1500	1.5	29.0	26.4	17.3	10.26	3.82	0.98	59.7	0.59	0.33	2.2	7.6	29	0.22	25	0.19	51
1600	0.0	26.5	21.0	12.8	10.77	NA	0.79	46.4	0.41	NA	1.6	6.9	23	0.19	24	0.20	47
1600	1.0	29.7	27.2	16.6	10.77	2.57	0.92	55.8	0.53	0.28	2.2	7.3	29	0.22	26	0.19	53
1600	1.5	30.4	29.8	18.2	10.77	4.01	0.98	59.7	0.59	0.33	2.3	7.4	31	0.22	27	0.20	54
1700	0.0	27.7	22.0	13.4	11.28	NA	0.79	48.4	0.41	NA	1.9	6.8	26	0.21	26	0.21	49
1700	0.5	29.6	25.3	15.4	11.28	1.26	0.85	52.0	0.47	0.22	2.1	7.0	27	0.20	26	0.19	52
1800	0.0	28.9	23.0	14.0	11.77	NA	0.79	48.4	0.41	NA	2.0	6.8	27	0.21	27	0.21	51
1800	0.5	30.9	26.4	16.1	11.77	1.31	0.85	52.0	0.47	0.22	2.2	7.0	28	0.20	28	0.20	55
1900	0.0	30.1	23.9	14.6	12.26	NA	0.79	48.4	0.41	NA	2.0	6.8	29	0.21	29	0.21	53
1900	0.5	32.2	27.5	16.8	12.26	1.37	0.85	52.0	0.47	0.22	2.2	6.9	29	0.20	29	0.20	57
2000	0.0	31.3	24.9	15.2	12.71	NA	0.79	48.4	0.41	NA	2.1	6.8	30	0.21	30	0.21	58
2100	0.0	32.5	25.8	15.7	13.21	NA	0.79	48.4	0.41	NA	2.2	6.8	32	0.22	32	0.22	58
2200	0.0	33.6	26.7	16.3	13.68	NA	0.79	48.4	0.41	NA	2.3	6.8	33	0.22	33	0.22	60

^a Average weight for a feeding period.^b Approximately 0.9 ± 0.2 lb of weight gain/day over the last third of pregnancy is accounted for by the products of conception. Daily 2.15 Mead of NE_m and 0.1 lb of protein are provided for this requirement for a calf with a birth weight of 80 lb.^c Dry matter consumption should vary depending on the energy concentration of the diet and environmental conditions. These intakes are based on the energy concentration shown in the table and assuming a thermoneutral environment without snow or mud conditions. If the energy concentrations of the diet to be fed exceed the tabular value, limit feeding may be required.^d Vitamin A requirements per pound of diet are 1273 IU for pregnant heifers and cows and 1773 for lactating cows and breeding bulls.^e Not applicable.^f Includes 0.34 Mead NE_m/lb of milk produced.^g Includes 0.03 lb protein/lb of milk produced.

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